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OF GLASGOW.

VOL. XXVII.

1895-96.

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CONTENTS OF VOL. XXVII.

PLATES.

PROCEEDINGS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

NINETY-THIRD SESSION.

PRESIDENT'S ADDRESS.

I.—*Dr. Kopp as Historian of Chemistry: Opening Address to the Philosophical Society.* By Professor JOHN FERGUSON, LL.D., President.

[Read before the Society, 6th November, 1895.]

ANOTHER year has sped away, and so swiftly, that it seems but a little time to me since I had to welcome you at the opening of a new session. Once more it is my privilege to repeat the welcome, and to congratulate this Society that while changes, inevitable changes, occur, there are always members willing and ready to take up the duties which would otherwise drop, and carry them on till a younger generation is prepared in its turn to continue the work begun so long ago. It is with a feeling of security and stability that we know that, though the *personnel* of the Society is ever varying, the Society itself remains; so that if those who started it could return now they would find us pursuing the aims they originally proposed, while they themselves would not be altogether strangers, however different the actual topics considered and the treatment of them may be since their time.

Ninety-three years ago the modern sciences were hardly in existence. There was some chemistry, mainly of a qualitative kind; there was hardly any electricity or magnetism; heat was unstudied; geology was just beginning; meteorology was unknown; steam and

gas were scarcely dreamt of; and yet people spoke then, as they do now, of the immense advances which were making in scientific discovery, and believed that there never had been such a luminous time. Our founders, anxious to know what was doing, fully alive to the importance of being on the crest of the advancing wave, established our Society, by which they could share their special acquirements with each other, and thus keep pace with the forward movement, though it was beyond the lifetime or the ability of each to master the whole. Even in those who had no opportunity of adding to the stock of knowledge, there was awakened a sympathetic interest, at least, in what was going on, and the area of instruction was thus widened. When one thinks of what has been done in recent years, and of what looms up in the future as possible, one wonders what will be the record during the ninety-three years to come, while we may all regret that we cannot have the privilege of knowing it. Some future president—perhaps my thirty-second or thirty-third successor—will be able to revert, when the time comes, to our doings, and lament that we were so ignorant; but I hope he will try to estimate us by the standard of our time, and not by that of his.

Out of consideration for that future president, I think it right and fitting that I should mention, at all events, one excellent alteration which has taken place since we separated six months ago. We no longer pursue our work in the gloom of Glasgow gas, but we have got a light by which we can, at least, see. I think I may congratulate the Society on this addition to the comfort of our meeting-place. I think also that I may convey the thanks of the Society to the House Committee for having carried out successfully the installation of the electric light. I trust the time is not far distant when the Society will be able to have this light throughout the whole building, especially in the library, where gas is so detrimental to the books, not to speak of the unwholesomeness of the air after eight or ten gas jets have been burning in it for hours.

One other change—and I should suppose that it, too, will be considered an improvement — is the new form in which the *Proceedings* of the Society appear. The substitution of a firm cloth binding for a paper cover is an unquestionable aid to the preservation of the volumes. These can now be placed at once on one's book-shelves without risk of tearing, soiling, or crushing; and as they are not like books of constant reference,

and need not be subjected to great tear and wear, the cloth cover should suffice to protect them as long as they are likely to be in one's possession. One is saved the cost of an expensive binding, and the *Proceedings* have now a more finished and permanent look.

In selecting a topic on which to make a few remarks this evening, I have thought that I could not do better than continue the theme of some of the addresses that I have already given, and put before you—in what, however, must be a very succinct and partial manner—a review of the labours of the late Dr. Hermann Kopp, of Heidelberg, in a field which he made pre-eminently his own—the History of Chemistry. I have often had cause to mention his name to this Society, and it was in my opening address only this time last year, that I referred to what he had done to clear up part of the obscurity that shrouds the early writers on the subject of transmutation.* The present seems to be a suitable opportunity for bringing his labours under your notice, for, though not an honorary member of this Society, we might well have placed him in that position, with distinction to ourselves.

Hermann Kopp was born in 1817, and died in 1892. He studied under Leopold Gmelin at Heidelberg, and under Liebig at Giessen. He became Privat Docent at Giessen in 1841, extraordinary and then ordinary Professor, and resided at Giessen for twenty-five years. In 1863 he went as Professor to Heidelberg, where he spent the rest of his life. His scientific researches, numbering more than sixty, refer chiefly to the borderland of physics and chemistry. He was the author of a treatise on Physical Chemistry, and one on Crystallography, and of some other books. His most voluminous publications relate to the history of chemistry, and it is on these I would now make a few remarks, leaving aside his other researches. I do so because the latter have been already subjected to an able exposition by Professor Thorpe—one of our own members—in a discourse before the Chemical Society, and are more likely to be familiar to chemists than the former, and also because the history of chemistry is a much less common study than ordinary experimental research. There is, besides my own personal interest in

* *Proceedings*, XXVI., p. 5.

the subject, the desire that I feel to acknowledge the assistance which the labours of Kopp have afforded me.

The chief treatises which Kopp wrote are the following:—

Geschichte der Chemie, in 4 volumes. Braunschweig, 1843-47.
Beiträge zur Geschichte der Chemie. Parts I. and II., - 1869.
Beiträge zur Geschichte der Chemie. Part III., - - 1875.
Die Entwickelung der Chemie in der neueren Zeit, 1 volume. München, - - - - - - - 1873.
Die Alchemie in älterer and neuerer Zeit, in 2 volumes. Heidelberg, - - - - - - - - - 1886.

—in all, nine octavo volumes.

The first of these, in order of time, is first in the order of merit, not only among Kopp's own works, but among all the histories of chemistry with which I am acquainted; in fact, it has an assured position as a classical work. Views as to the value of the subject, as to its treatment, as to what falls strictly within its domain, will certainly vary, but nothing can deprive this work of the position which it occupies in historico-chemical literature of being the first to give a systematic view of the history from all sides and in all its sections. The arrangement of the subject is masterly, and displays not merely a necessarily great familiarity with the details, but an unrivalled power of bringing widely diverse material under its appropriate heads.

The consideration of Kopp's labours naturally suggests the questions—what was the state of the subject before he took it up? in what state did he leave it? and what were his contributions? Prior to Kopp there had been a great amount of independent research upon the subject. The early historians struggled hard to enhance the importance of the science by carrying its origin back to the earliest possible times, and by enrolling the most famous physicists of antiquity amongst its students. Later writers, when they found it difficult to hold that position, struggled equally hard to maintain the value of the science, especially for its practical advantages, against those who took every opportunity to decry it. Even in quite recent times, it was still the fashion for authors of text-books, as well as professors in delivering anything like a systematic course of instruction, to preface the subject with a a discourse on its importance and a history of its origin and development more or less elaborate.

To some extent apologetic in tone, these later histories and historical sketches looked rather askance on certain epochs in the growth of the science. They did not dare say that there might not be some reason in the theory of a common origin of the metals, and that, though many of those persons who tried to demonstrate the truth of the theory were undoubtedly adventurers and swindlers, it did not follow that all who laboured at the realisation of the hypothesis were equally untrustworthy. Still, the apparently fruitless labours of the alchemists, coupled with their high-sounding claims, made cool-headed persons doubtful of a study which could engender such vagaries. In the face of all that, the devotees of the real science had to maintain its value and importance, both in itself and in its applications. Hence, during the early half of the present century, the chemists passed over the alchemical period with as light a touch as they could well apply. They could not deny the existence of alchemical theories, and they could not but admit that they formed an integral part of the thoughts of mankind about the changes of matter, but they were glad to get rid of them as soon as they could, and pass on to something positive in what was considered the path of discovery and progress. They were still too near the time when these beliefs had prevailed and had been scorned, for them to investigate them scientifically and minutely, ascertain what they signified, and trace their history back to its origin. That was beyond the data which they possessed, and they did well, therefore, to leave such questions alone altogether, and go on with the work which lay to their hand. The time was hardly ripe for such investigation, although the material for it existed in abundance. What was wanting was the requisite preparation in historical and archæological investigation.

This is obviously the case in what may be reckoned the first of the quite modern histories. It was the work of one whom I have had the privilege to succeed both in the University and in the office which your kindness has conferred upon me—I mean Professor Thomas Thomson. He was the author of the first systematic history in recent times, and it was published so long ago as 1830. In sixty-five years a science like chemistry does not stand still, and I need hardly say that Thomson's history would not satisfy a modern student of the subject, either by its contents, its treatment, or its conclusions. It is, indeed, a straining of the term to call it a history at all, with more recent works before our eyes. When the author deals with events coincident with his

own lifetime, he is interesting, for he supplies original information. But when he has to enter into historical research, and estimate men and events in their own surroundings rather than in his, he displays a lack of critical insight and impartial judgment, of unprejudiced narrative, and of an appreciative statement of fact, all of which elements are as indispensable to historical as to scientific research. But, imperfect though it be, Thomson's history remains the only original attempt in English at a brief, and yet comprehensive, account of the progress of chemical science; but it has long since disappeared, and no one now not specially concerned with the topic would think of doing more than consulting it for certain points. I had occasion, some years ago, to point out the defects of Thomson's work—in one section of it, at least,—but it is unnecessary to refer to the matter again. It may be said that the full treatment of that section was not demanded by his scheme, but in that case he should have passed no judgment upon it without proper inquiry; least of all, should he have practically shown that he considered the theme not worth examination.

Several years elapsed, and then appeared a history which had a great amount of good in it, though the execution was faulty in several ways. This was the *Histoire de la Chimie*, by Ferdinand Hoefer, which came out at Paris in 1842-43, in two volumes, and again, in two volumes, in 1866-69. The chief merit of this work lies in its clear perception of the extent of the subject, the absence of prejudice, and the sympathy which the author has with the conscientious views of every one whose work he describes, no matter whether they be right or wrong. He, perhaps, carries this cordiality too far in certain cases, and ascribes to some of the old chemists a knowledge of facts, or a recognition of some general view, which it is hardly possible to believe was intentional on their part, but only a fortunate guess or anticipation. He was the first, however, to throw any light on the Greek period, and courageously to state, or at least to imply, by his own example, that the Greek writings were worth investigation. He printed portions of the originals, and gave the period quite a prominent place in his *Histoire*. In arrangement, however, the work is defective, as it is purely chronological, and the attempt is made to carry forward all the sections of the subject as far as may be simultaneously; but the result is rather distracting, for, instead of a consecutive narrative of each department, one gets portions

of each in the different periods, so that one thing is jostled up against another. But Hoefer's is a readable book, and it is certainly a very great advance in several respects, most markedly in comprehensiveness, on Thomson's. Hoefer was fond of the subject, took a generous view of its importance, and included in his treatment, not merely the authors whom one must acknowledge as having either done chemical work or written chemical treatises, but those who, without being chemists in the narrower sense, contributed to the advance of the science through technology and pharmacy.

Just a year later than Hoefer's *Histoire* appeared the first parts of Kopp's *Geschichte*. This at once took the foremost place, as by far the most systematic and best executed work on the subject. No one can read it now, even with the additional light which the author himself has thrown on many sections of it, without recognising it as a most skilful exposition of the subject within the limits which the author had prescribed.

The history of science may be dealt with in two ways: either as a theme of minute research, or as a philosophic survey of generalities. Kopp has given us instances of both. In his *Beiträge* and in his *Alchemie* he has given us not only the narrative, but he has also put before us in most elaborate form the authorities upon whom he depends, and has discussed most minutely and painfully the controverted points which such an investigation is certain to bring to light. But in his *Geschichte* he has left out all authorities, and confined himself to a readable and consecutive narrative of the past events in the science, viewed under different aspects. This is one of the points of exposition in which Kopp has surpassed his predecessors. He has clearly recognised that it is impossible to treat under one rubric the multitudinous details of a subject like chemistry, with so many ramifications and so many lines of progress. The students of the history, then, are indebted to Kopp, not perhaps for the actual division of it into periods, for such a division is forced upon us at the very beginning by the succession of the events, but for carrying out this division and classification throughout.

When one considers such a great branch of human activity and thought, and tries to find how one idea or one discovery has come out of another, it will at once be seen that there may be advance in many directions simultaneously, and that these may be considered more or less independently of one another, and, indeed, must

be so treated if the development is to be understood. It might be possible, for example, to write a history of chemical theory, which would not deal necessarily with a systematic review of analysis. A complete history ought to contain a narrative, not only of the progress of the science generally under the domination of certain leading ideas, but also that of the various branches of it. It was part of Kopp's merit not only to recognise this, but to carry it through systematically in his *Geschichte*, and it is this which gives his work superiority over its predecessors. Accordingly, the first section was devoted to the consideration of the progress of the science from the earliest period, when it can be said to have had a definite existence, down to the author's own time. It falls into five great sections: the early period; the alchemical period; the medical period; the phlogistic period; and the oxygen period, or, as Kopp calls it, the period of quantitative investigation. These periods display well-marked characters; the men who worked during them were more or less under the influence of certain general beliefs which directed their investigations to the solution of certain problems, and led to certain discoveries. Under this general head, therefore, fall to be considered the lives of these chief workers, and to what extent the general idea was exhibited in their works. As I pointed out in my first address as President of the Society, science at any particular time consists of the ideas of the most prominent men of that time. It is their influence which guides others less gifted, and so their thoughts become, for the time, the thoughts of less original men. Just, however, because there are critical forces working at all times to disintegrate, each period contains the germs of its own modification or abolition. If it were not so, the theories of that period would be final, and would embrace all possible subsequent discovery. In the history of chemistry, however, it has not been so, and the most interesting sections are those in which the transition from one theory to another is described. It is in the discussion of opposite views that historical interest lies. Dr. Kopp has been alive to the importance of such transitions, and the sections in which he has considered the causes of the superseding of one view by the very discoveries which it has been the means of bringing to light are among the most important in his book.

But this forms only the first or general division. What follows is a historical treatment through the successive periods already mentioned of particular departments of chemistry; the details of

the history of analysis, of mineralogical and pharmaceutical chemistry, and of alchemy, cannot be brought under the general survey. There is the special history of the theories of chemical action, and of the laws of combination; there is the history of the name, of symbols and nomenclature, of the chemical elements, and of chemical action, such as combustion, the history of the metals, and non-metallic elements, and of carbon and its compounds. All these branches and others were reviewed by Kopp with a fulness which reveals an amount of reading and an amount of labour and skill in arrangement which give him the first place among the historians of the science.

Of course, it must not be forgotten that the book is at this moment celebrating its jubilee, for the third volume was published in 1845, and it is not possible that it can contain more than was known at that time; but one must estimate it, not by what may be our standard now, but by what had been done and what was possible to be done then. Judged by the latter, then, as a systematic history of chemical science, it not only surpasses anything earlier, but nothing done since, even by its author, is comparable to it. It may be admitted that it is not complete even within its own range; there are many names that do not occur in its pages; there are expositions of fact and theory which have not been included either in the general history or the special sections; there are inaccuracies of date which could be corrected; but these do not in any way detract from the supreme merit of the work as a whole, or make it less readable. It only affords other students of the subject an opportunity to work up these omitted details, and so carry on the work already executed with such skill by Dr. Kopp.

If anything were required to prove that the work was not complete, it is the labour expended in the same field by the author during the following forty years. Upwards of twenty years elapsed before Kopp produced anything more on the subject. Then, in 1869, came his *Beiträge*, to which I have often referred before this Society. The first two parts were devoted to a critical examination of the whole extant literature regarding the Greek alchemical MSS. If, in his first work, Kopp gave us results only, in these essays he did not stint his authorities. This, of course, rose from the nature of the inquiries. The first dealt with facts and theories—how the former were discovered, how the latter began, flourished, decayed. But the second was concerned with

statements in books about other books, manuscripts, and authors, so that these had to be quoted to make the arguments based upon them intelligible. In its own way this work is quite as notable as the other, but it cannot, in the nature of things, ever attain its popularity. The *Geschichte* appeals to every student who desires to have some intelligent appreciation of the vicissitudes through which chemistry has passed; the latter appeals only to the student of the antiquities of one period of the science. As far as it goes, this work practically exhausts the subject. Still it is not complete; here also are details to work out and inaccuracies to correct; but it is only those who, having tested the work and engaged in similar lines of research, can appreciate the vast labour which these volumes represent, and the scrupulous care which Kopp has exercised to make them as accurate as possible. Six years later came the third part of the *Beiträge*, which contained an equally elaborate discussion of the views of the leading chemists from Geber to Stahl as to the aim of chemistry and the fundamental constituents or elements of bodies. This forms practically a supplement to the first volume of the *Geschichte*, and the material is said to have been collected with the intention of bringing out an enlarged edition of that work. I cannot help thinking that it is fortunate that this plan was not carried out. The *Geschichte* as it stands now has a unity of design and of idea which is not only satisfying to the reader, but represents exactly the stage of knowledge and of historical views which the author had acquired at the time. To have attempted to amalgamate the gatherings of thirty years with that unity could hardly have been successful. There would have been a mixture of the old and the new which would not have satisfied the chemist, would certainly not have satisfied the student of the detailed history of the science, apparently did not attract the author to attempt it, and would have spoiled the homogeneousness of the book. For my own part, I value much more highly, as contributions to the study of chemical archæology and antiquities, these elaborate and minute essays than a summary, however masterly, which would have involved a repetition of the work to discover the data, if wanted, upon which the summary is based. Moreover, one sees more of the author himself in these collections, of his way of working, and of the intimate and comprehensive knowledge which he had of the subject.

In the interval between the publication of his papers on the Greek alchemists, and those on chemistry subsequent to Geber, he wrote his book on the development of chemistry in modern times, practically from Lavoisier to the year 1858. It covers, therefore, part of the ground already examined in the *Geschichte*, but the examination is far more elaborate, and it is carried on into the period subsequent to 1840, which is about the limit of the earlier history. This work was written for the series issued by the Bavarian Academy of Sciences at Munich, and it is, I think, the least successful of the author's histories. Whether that is due to the material or to the proximity of the historian to the time depicted, it is difficult to say, but the work partakes more of the nature of a historical text-book than a real history. It is none the less valuable and useful as a book of reference, but it lacks the classical finish of the *Geschichte* on the one hand, and does not display the lavish scholarship of the *Beiträge* on the other.

The last contribution to the subject which Kopp made was not one of the least remarkable. It was the two volumes on alchemy, published in 1886, and in them he printed the collections which he had made for many years upon this most curious subject. He had already, in the second volume of his *Geschichte*, devoted considerable space to the subject, but these last volumes show how much there was still to do. His treatment is of the same thorough kind—at least, as far as Germany is concerned—as he displayed in the *Beiträge*, and it consists of a long series of monographs on certain prominent persons, events, and ideas, which are followed by still more elaborate notes upon points of detail. There is also a very full section upon German alchemical books, which, to those who have taken any notice of that very singular literature, is both interesting and amusing. Mixed up with the later alchemy there is Rosicrucianism, and to that, too, Kopp devotes a considerable amount of space. It is right, however, to say that Kopp takes what seems to me to be a correct view of the later developments of the subject—namely, that they were concerned not with physical science, but with mysticism, and that the language of physical transmutation was really applied to certain religious views. He therefore correctly designates his work a contribution to the study of culture, and not a contribution to the history of chemistry. To this result he was led by long acquaintance with the literature, and by finding no physical questions really discussed therein. But as

both alchemy and Rosicrucianism in a manner hang on to the older alchemy, which was one of the phases of chemistry, it is not possible altogether to ignore the later developments, and, anyhow, no one was better qualified to deal with it than was Dr. Kopp.

From what I have now so very briefly said, you will be able to gather not only the universal range of Kopp's historical knowledge, but, what is of still more value for those who succeed him, of his publications. They represent protracted and continuous labour, great skill in describing the events of history, fairness in estimating the work of former chemists, and a scientific grasp which thinks nothing too small or unimportant to be ascertained with accuracy, and fitted to its place in the general scheme.

If Kopp by his researches has won fame in physical science, not less does he occupy a unique place among those who have devoted themselves to the history of science. I have felt it to be an almost sacred duty to put on record the importance which I attach to these elaborate and comprehensive historical investigations, which may be superseded or amended in a few details, but are not likely ever to be excelled, either as works of scholarship, or of historical art.

In my first address as President I indulged in a retrospect of the work of the Society during its existence hitherto. That is an easy task, since the *Proceedings*, for at least thirty years past, afford abundant material for its performance. Now, when I am on the point of demitting office, and handing over to another the duties of the chair, I would I were able to give a forecast of what may be the future of the Society. I am no prophet, however, and need not attempt such a thing; but while one can never say what will happen, one can always express a wish, and try to attain what one would like to happen. In a society like ours, composed of members with such different interests and engagements, who wish to know rather what is doing than to attempt the doing themselves, the contributions are necessarily drawn from a comparatively small number. The tendency, therefore, as I showed on that first occasion, is for the Society's work to run in certain grooves, so long as a given subject, either through its intrinsic and immediate interest, or the activity and energy of those prosecuting it, is a dominating one. What may be the coming line which the Society will follow, I should hardly venture to predict. One

cannot tell how soon it may be diverted into quite a new direction.

There is, however, one matter of which I would venture to remind the Society, especially as I can do so without any prospect of having an active share in the carrying of it through, for the event will not be due for the next half-dozen years.

The Society, I believe, was founded in 1802; in 1902 it will celebrate its centenary. How that is to be done, and what form the celebration will take, will rest with the office-bearers of the time, and no plan that could be formed now would be altogether suitable when the time for executing it shall have arrived. There is, however, one thing that the President and Council, indeed, all our members, might plan and so work for during the next few years, that when the centenary meeting is held, the President on that occasion will be able to announce that, thenceforth, this Society will be known as the Royal Philosophical Society of Glasgow. It may be that, for good work during a hundred years, and the certainty of no inferior work emanating from it in future, a Royal Charter of Incorporation may be obtained, with the status and privileges which such recognition confers. Whether it be possible to accomplish this or not, or what steps may be required to attain this end, if it be possible, I am hardly in a position to detail; but as it takes some little time, the Council should bestir itself, so as to have all the formalities complied with, and the title and charter obtained when the hundred years have elapsed. I hope that, though not your President then, I may have the satisfaction at least of knowing that what I have now suggested has been of use, if it help to put us in a better position than we now occupy. The Philosophical Society of Glasgow must now be reckoned among the older societies of the country, and it should have its status assigned to it accordingly.

II.—*Note on the Stereophotochromoscope: A New Optical Instrument.* By DAVID FRASER HARRIS, B.Sc. (Lond.), M.B., C.M. (Glasg.), Assistant to the Professor of Physiology in the University of Glasgow.

[Read before the Society, 6th November, 1895.]

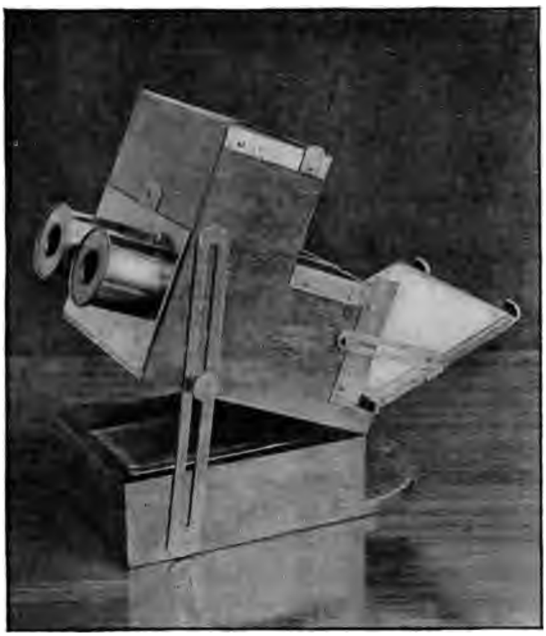
INTRODUCED through the kindness of Professor M'Kendrick, I have the honour to bring before your notice this evening an instrument which is at present the only one of its kind in the United Kingdom, having been brought here by the courtesy of its owner, Mr. William H. Ward, of London.

The Stereophotochromoscope, which is the name given to the instrument, is the outcome of a laborious experimental research by Mr. Frederick E. Ives, of Philadelphia, who has solved one aspect of the problem of "photography in colours." Mr. Ives does not, indeed, provide us with a portable coloured photograph, but he has constructed an instrument for viewing colourless photographs, which reproduces for us all the colours and tints, lights and shades, presented by the object or landscape, with as much fidelity as the phonograph reproduces the tone and quality of sounds. In addition, it is a stereoscope, for it gives us the illusion of a solid body—a result obtained by photographing the object, picture, landscape, or human face from two points of view,—a right and a left,—in accordance with the well-known laws of binocular vision. There are, then, essentially two processes involved:—

(1) The photographing of the coloured object by a specially-constructed triple camera, to yield, by a single exposure upon *one* sensitive plate, three double (or stereoscopic) "negatives." Each of these pairs of negatives is "taken" by a different, coloured light, the nature of which I shall describe immediately; but no one of the "negatives" possesses any colour in itself, nor, of course, do their corresponding "positives," which are printed as transparencies upon glass in the ordinary way. (See Fig. 1*b*.)

(2) The viewing of these transparencies in the instrument before us (see Fig. 1*a*), the three photographs being illuminated by light of different colours—red, green, and blue-violet—for each, respectively. The three right-hand images are, by ingenious reflections, accurately superposed upon the retina of the right eye, the three left-hand images being similarly combined upon the corresponding retinal point in the left eye, and thus is produced the impression of a solid coloured body.

FIG. 1*a*.



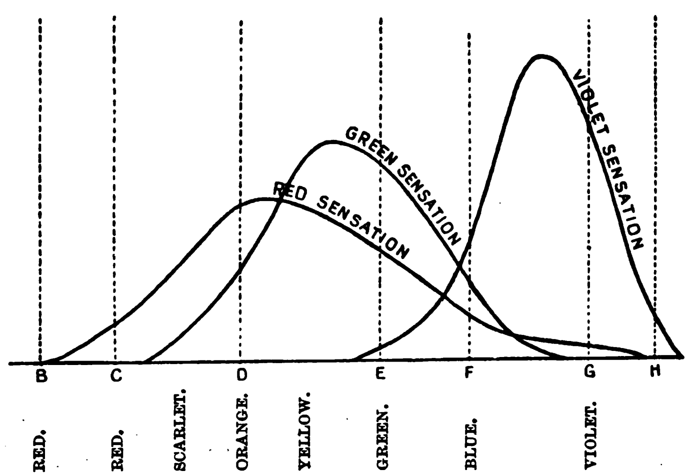
THE STEREOPHOTOCHROMOSCOPE.

The inventor, without adopting the physiological conceptions of the Young-Helmholtz theory of colour-vision, did, nevertheless, work from the beginning upon the physical axioms underlying that theory, and he has arrived at his most striking results by accepting the mathematical and physical data first given us by Clerk-Maxwell and Helmholtz, and subsequently somewhat modified by Captain Abney, F.R.S. Briefly, the Young-Helmholtz theory declares (1) That there are three "primary" colours—red,

green, and violet: those which cannot be produced by any mixture of any other colours; (2) that there are three varieties of "end-organ" in the retina; one of them is powerfully stimulated by red and orange rays, less so by green, least of all by blue-violet; the second set are especially excited by green light, and less so by spectral rays on either side of it; and the third set are most susceptible to violet light, less so to green, least of all to red; (3) that by a stimulation of all three "end-organs," in nearly equal intensities, we perceive white.

By Maxwell and Abney's "method of mixture" (in which white light and all spectrum-tones are "matched" by mixtures, in various proportions, of two or three of the pure or "primary" colours), we are able to construct for each fundamental colour-sensation a curve whose abscissa is equal to the length of the visible spectrum, and whose height, at any point, is a measure of the degree of intensity with which the spectral tone at that point is able to stimulate the fundamental colour-sensation corresponding to the curve in question. (See Fig. 2.)

FIG. 2.



ABNEY'S DIAGRAM OF THE THREE PRIMARY COLOUR-SENSATIONS.

B to H—Position of the Fraunhofer lines in solar spectrum.

In illustration, let us take a point in the yellow-green region. Referring to Abney's method, we find that the colour at this

point could be matched by a mixture of the primaries in some such relative proportions as—red, 10 per cent.; green, 85 per cent.; violet, 5 per cent.,—from which we conclude that, since a small amount of pure red was necessary in the mixture formed to match yellow-green, yellow-green must stimulate the fundamental red sensation, though only to a small extent compared with the degree in which it stimulates the fundamental green sensation: similarly for other intermediate spectral colours. Thus, not only does red stimulate the fundamental red sensation, but each of the following—namely, red-orange, yellow, yellow-green, and even blue—stimulates it; so that the simultaneous joint action of all these rays would stimulate the fundamental red sensation to the full; and analogously for the other two fundamental colour-sensations.

The length of base of any one curve indicates the totality of spectral rays efficacious in exciting in any degree a particular colour-sensation. Ives therefore argued that, in order to get a photographic representation of all the parts of a coloured body which could appeal, we shall say, to the fundamental red sensation, he must photograph the object with a selective glass colour-screen placed in front of it, of such a colour that the light coming through it should act upon a sensitive plate in a manner similar to that in which all the rays capable of exciting the red sensation would act upon the retina; and analogously for the other two negatives. Each negative, without having any colour in itself, would, in this way, be a record of such parts of the object as emitted rays capable of affecting that particular fundamental colour-sensation which would be stimulated to the full by light of the tint of the colour-screen interposed between the object and the sensitive plate. Ives' own words are—"It is therefore only necessary, in order to secure action by different rays in any definite proportion, to use such a combination of sensitive plate and colour-screen as will yield a spectrum-negative having a density-curve corresponding to the graphic curve representing such proportionate action." *

How this was done is a matter full of technical details fully intelligible only to the scientific photographer. Ives accomplished it after constructing a special triple camera which sends the incident light in three different directions to the one sensitive

* *Journal of Society of Arts*, May 27, 1892.

plate during only one exposure. The obvious difficulty of having three negatives taken on the same plate, with lights of different rates of actinic action, was also overcome in two ways—either by using a larger diaphragm for the reddish light than for the others, or by reducing the intensity of the two sets of the more active rays by interposing in their paths screens of smoked or ground glass.

The coloured rays used in the Stereophotochromoscope for viewing the transparent photographs (or "chromograms," as they are called) are the three "primary" colours—*pure* red, green, and blue-violet; for, although it was necessary to employ for taking the photograph all the rays efficacious in exciting a fundamental colour-sensation, we objectively represent the conscious fact of a colour seen, by employing only one ray of some particular colour. This point, which is of great importance, may be better understood from an example. Although, as already shown, physical experiment compels us to believe that yellow-green light affects the fundamental red sensation, yet when we come to represent the fact in consciousness of a colour (whose objective counterpart is the stimulation of the "end-organs" for the fundamental red sensation), we must use as an illuminant only *pure red* light.

Fig. 1*b*.

The Chromogram.

This is attained by using a powerful white light (Welsbach or electric arc) as the source of illumination, and interposing between it and the chromogram, which represents the action of light upon the fundamental red sensation, a pure, red, glass colour-screen, and analogously pure green and blue-violet screens for the other two chromograms, respectively. The coloured images formed in the Stereophotochromoscope may, of course, be thrown upon a screen, and so displayed to a number of spectators at once, but the stereoscopic effect is thereby necessarily lost.

The time of exposure being relatively long (two minutes) does not make it suitable for portraits, but for all scientific purposes in the hands of ethnologist, anthropologist, geographer, and

explorer, it will be of great service. By it the dermatologist can obtain a more accurate record than even an artist could give him of the exact colours and tints in skin diseases. Such a method of recording and reproducing personal chromatic characteristics would be of great value in the Criminal Investigation Department. To physiologists it is an instrument hitherto unrivalled for demonstrating certain of the physical facts underlying the Young-Helmholtz theory. Whether we fix our attention upon the literally brilliant results of this instrument, faithfully showing, as you will presently see, apples, grapes, bananas, and peaches in one dish, and the bons-bons in the other, with all their own splendid colouring reproduced, or whether we think of the laborious research and patient conquering of every form of difficulty ere this was done, we must declare the achievement is that of a true man of science, having a profound practical knowledge of chemistry, photography, chromatics, and geometrical optics.

Figure 1*a* shows the instrument as ready for use.

The upper horizontal face carries the "pure" red glass.

The lower horizontal face carries the "pure" green glass.

The vertical face nearest the plane mirror carries the "pure" blue-violet glass.

The "chromogram" (Fig. 1*b*) is in three pieces, jointed together to admit of this chromatic illumination in three different planes.

x rests upon the upper horizontal face.

y rests upon the lower horizontal face.

z rests upon the vertical face nearest the mirror.

III.—*Immunity to Infective Diseases: A Pathological Study in view of Recent Researches.* By Joseph Coats, M.D., Professor of Pathology in the University of Glasgow.

[Read before the Society, 20th November, 1895.]

I do not know that any explanation or apology is needed for addressing this Society on a pathological subject. It is unusual, but I may presume that, as a society, we claim to include all kinds of wisdom, and that there is nothing which has truth and fact in it that lies outside our scope. I thought also that it might not be unwelcome to some to get a glimpse into a field with which they are perhaps unfamiliar.

The subject which I have chosen—that of Immunity—has its important practical aspects, which have already been ably dealt with in this hall. I may at once warn you that the pathologist's point of view is that of observation and scientific inference, and not directly the practical one, although our subject itself is an illustration of how the practical often closely follows the scientific. To my own mind the subject is one of extreme interest as a mere matter of pathological study, and it is purely from this point of view that I have chosen it for to-night's discourse, in the hope that I may be able to impart to my audience some of the interest which I myself feel.

Immunity and susceptibility to disease may be regarded as the converse of each other. Immunity is non-susceptibility, and susceptibility is non-immunity. When we speak of any specific disease in relation to mankind, we imply a certain susceptibility on the part of human beings to that disease; but when we come to regard individual men, we discover an extraordinary difference in the degrees of susceptibility, and, conversely, in the degrees of immunity. These variations are most readily demonstrable and most easily studied in diseases whose causes are somewhat fully known, and such are some of these that belong to the group of Infective Diseases.

Infective diseases may be defined as those which, demonstrably or by reasonable inference, are due to the invasion of the body by parasitic organisms, mostly of microscopic size. The body is infected by these organisms; but, as the infection may come from the outer world and not from our fellow-men, there are many of these diseases which are not infectious, in the sense of being communicable from one person to another. I may at once make this matter clear by adducing an example of an infective disease which is not an infectious one, and for this purpose I shall choose tetanus, or lockjaw. There is frequently present in the earth of gardens, streets, and elsewhere, a microbe which, presumably, plays some part in the economy of nature in these positions. This particular microbe, when carried deeply into the tissues of a living animal, as it may be by a penetrating instrument or article polluted with dirt from one of the sources mentioned, will sometimes live on in the tissues and multiply there. As a product of its vegetative growth, it produces a poison, or, as it is now the custom to call such products, a *toxine*, of intense virulence. It is a poison which affects specially the central nervous system, producing symptoms often of a very violent character. The microbe remains local, and produces little or no disturbance, but it sends off its deadly products, which produce the symptoms of the disease. This microbe, like many others, has been cultivated in glass vessels, or, as it is briefly expressed, *in vitro*, outside the body; and when so grown, it produces the same poison as it does in the body. The poison can be separated from the "culture," and, when introduced into the body, it produces symptoms similar to those produced by the microbe when it grows inside the body. The microbes, whether of this kind or of any other, when they multiply in the bodily tissues and so produce diseases, are only following the natural course of their propagation, and the living body is merely a medium for their culture, just like any other material suited to the purpose.

But the body of a living animal is something very different from dead animal matter; and if the microbes are, as it were, indifferently carrying out the phases of their life-history, the living tissues are by no means the indifferent victims of their energies. The animal body is not a mere mass of flesh and bone, but is to be regarded as an aggregate of an incalculable number of living units, which we are accustomed to call *cells* or *corpuscles*. These, though much larger individually than microbes, are still of microscopic size. Each possesses its own separate vitality, and

all the actions of the body, of whatever sort, are ultimately resolvable into cellular actions. We are therefore to regard the body as in itself a state, or union of states, in which there are myriads of separate individuals, bound together in one confederacy, but bearing various relations to the whole. It is into this great commonwealth of living units that the microbes intrude themselves, and we may well suppose that the cells are not indifferent to the invasion.

In the further study of this matter, it is necessary to separate carefully in our minds these two—the microbes on the one hand, and the toxines, which are their products, on the other.

Taking first the poisonous products of the microbes, it may be said that the symptoms of the various diseases concerned are the results of the action of the toxines on the living cells of the tissues. They may be produced artificially by the toxine without the microbes being present in the body at all, or they may be produced by the toxine acting on one part of the body, while the microbes are situated at a different and perhaps a distant part, as in the case of tetanus, already mentioned.

On the other hand, in regard to the microbes, it is to be said that those concerned in the production of disease are only a small contingent of the great class to which they belong. In regard to all microbes, there is an opposition on the part of the living tissues to their intrusion, and it is only those which successfully overcome this resistance that become the causes of infective diseases. The great bulk of the microbes prey on dead matter alone, and are entirely barred from any invasion of the bodies of living animals. Those which are capable of obtaining a footing may owe this power to different circumstances. In some instances it seems as if they owed their ability in this direction to their own inherent vitality, whereby they are able to resist the control of the living tissues. In the majority of cases, however, it seems more probable that it is due to the influence of their poisonous products that they obtain a footing in the body; that is to say, when a few microbes are introduced, as must usually be the case in the beginning of most cases, they, by means of their toxines, paralyse the opposition of the cells, and so secure their position for further growth. This is well illustrated in the case of the tetanus microbe. If the spores of the microbe, carefully freed (by washing or otherwise) from the toxine, be introduced into the tissues in quantities which are not too great, then tetanus is not

produced. In order to obtain a footing, they require to be accompanied either by their toxine or by some agent which will damage the tissues whilst they slowly multiply. It is found that various matters, including the products of other microbes and substances of various sorts, are able to give, as it were, the start to the tetanus microbe, and that even a direct injury to the tissue may do so. It is obvious that, in what may be called the natural mode of acquiring the disease, dirt containing microbes of various kinds is introduced, and the tissues are injured, so that the necessary conditions for the growth of the microbe are furnished.

Such being, in the briefest possible sketch, the general facts in regard to the parasitic organisms which produce infective diseases, and the bodies of living animals, which are the seat of their energies, let us now turn to the subject which is more specially before us. From what has been said as to the relation of the living microbes on the one hand, and the living cells on the other, it may readily be inferred that there are differences amongst animals in regard to the various reactions of cells and microbes. Although the living structures of animals are all ultimately composed of cells, yet these cells have, in different animals, and in different parts of the same animal, variations in structure and endowment, and we are not surprised that these differences manifest themselves in this matter of susceptibility. Let me in a few words mention, in regard to tetanus, some of the facts ascertained as to the susceptibility of different species of animals to this form of infection. The horse is known to be singularly susceptible; so also is the guinea-pig; and, to a somewhat less degree, the mouse. The rabbit is still less susceptible, and the rat less than the rabbit. The sheep, the dog, and the pigeon are very slightly susceptible, and the domestic fowl is insusceptible to ordinary inoculation with the microbe. Each species of animal, with its inherited and inherent constitution, has its own specific relations to the parasitic organisms, which are the agents of infective diseases. The same applies in a less degree to the races and varieties of the different species, and in a still less degree to the individuals of each race. A striking difference in susceptibility as affected by race is exemplified in man in the case of yellow fever. The negro race is almost immune to this disease, which is so virulent in persons of the white races. It is also known that in the case of diphtheria, scarlet fever, typhoid fever, &c., there are striking family and personal peculiarities in susceptibility, and, conversely,

in degrees of immunity. It is in this sense that we speak of Natural Immunity, which is part of the constitutional endowment of the animal, and depends, like the other items of his constitution, on inheritance.

If we inquire as to the exact significance of Natural Immunity, we are on more difficult ground. When microbes find their way into the body of an animal which is naturally immune, what is the precise method by which they are disposed of, so that the disease does not develop? It may be stated, at the outset, that it is not because the toxines are not poisonous to the animal. An animal which is immune to the disease as introduced by the microbes is quite susceptible to the poison introduced, with or without the microbes, as when the toxines are used. There is, of course, no proper infection; the disease is not established. It is simply a case of intoxication or poisoning; the symptoms depend on the dose of the poison, and disappear when the poison is exhausted. Natural immunity is a matter of the microbes in relation to the living structures of the body. The fact may perhaps be stated with sufficient accuracy by saying that, in the case of an animal possessing natural immunity to a particular disease, the microbes concerned in that disease are simply relegated to the same category as the great majority of microbes, which, as we have seen, are barred in their attempts to obtain a footing in the body. The modes in which the former are disposed of are, presumably, not different from those applicable to the latter. The manner in which the entrance of microbes is barred, and in which they are dealt with if they obtain entrance, is not fully understood. Probably there are many ways in which these objects are effected, and here, as in all the vital actions of the body, we must look to the active units of the body, the cells, for the explanation.

Some of the possible modes may here be mentioned. For one thing, the various surfaces of the body are covered with a close phalanx of cells, generally in several layers, and these, whilst effectively preventing the entrance of ordinary microbes in all animals, may in the case of immune animals prevent the entrance or lodgment of infective microbes. They may do so by the power which a living body has of preventing the entrance into its substance of foreign bodies, unless it takes them into itself for the purposes of nutrition.

Again, if the microbes get beyond this external boundary, the living cells may deal with them by taking them into their

substance, nullifying them, and ultimately digesting them. This mode of disposal has been worked out with great industry and ingenuity by M. Metchnikoff, who has devised the name "Phagocytosis" for the faculty which many cells have of taking up and digesting particles of matter capable of being assimilated. The observations of Metchnikoff show that in the case of some of the best-known infective microbes, such as those of anthrax and of tuberculosis, when these are introduced into immune or partially immune animals, the living cells of the tissues take them into their substance, and dispose of them. The microbes undergo certain alterations in form and reaction to staining agents, and finally become assimilated by the cells.

Besides these modes, it is not improbable that the living cells may, in the presence of microbes, emit some substance which is capable of paralysing the microbes, and that, when thus weakened or killed, they may be taken up by the cells and digested. This has been asserted more especially in regard to the free wandering cells, which form an important constituent of the blood.

Again, it is not unlikely that in some cases the blood of an animal may be uncongenial by reason of some peculiarity in its chemical constitution to particular microbes. It is an ascertained fact that the blood-serum of some animals is unsuitable for the cultivation of certain microbes, although generally blood is a suitable medium. But this is not to be regarded as at all a general explanation of immunity, as the blood-serum of immune animals has in certain cases been found quite adapted to the culture of the microbes to which the animal itself is immune.

Another possible view is that in certain animals the cells may be less sensitive to the toxine, and the microbes are thus deprived in some degree of their aid in overcoming the resistance of the tissues. I may here recall what was said in regard to tetanus, in which we saw that the toxine, or some agent which acts on the tissues, is necessary, as well as the microbes, in order that the latter may obtain a footing. It is consistent with this that in animals which present immunity only in minor degrees, a larger dose of the agent will sometimes suffice to produce infection.

We may now leave the subject of natural immunity, with the remark that in it we are concerned directly with resistance to the entrance and propagation of the microbes, which are the infective agents, and that in this contest the active cells are, in some form

or other, by their inherited endowments, the opponents of the intruding agents.

It is in the domain of Acquired or Induced Immunity that we have had of late the principal advances in our knowledge. It must have been early a matter of observation that, in the case of such diseases as smallpox, measles, and scarlet fever, a single attack conferred a high degree of immunity against further attacks. There is thus an acquired immunity. It was the knowledge of these facts that begot the idea of producing immunity to smallpox by actual inoculation with the virus of the disease. This was the first attempt at procuring what we may call induced immunity, which is obviously of the same nature as acquired immunity. This method of preventive treatment against smallpox is stated to have been of considerable antiquity. The modern knowledge of it dates from about the year 1715, and, curiously enough, it comes from the Turks at Constantinople. In that year, Dr. Kennedy, a Scotsman, wrote about inoculation for smallpox as practised in Constantinople. Its introduction to this country was, however, essentially due to Lady Mary Wortley Montagu, whose husband was ambassador at the Ottoman Court. She not only wrote to a friend in England describing the method, but, in the year 1717, she had her son inoculated, being the first British subject on whom the operation was performed. The matter taken from a smallpox patient was inoculated in one arm by Dr. Maitland, surgeon to the embassy, and in the other by an old Greek woman, who had been many years in the habit of inoculating. The disease ensued in due course, and there were about 100 pustules. Here was the induction of an actual disease (which generally occurred in a mild form, but was not without its fatal cases), in order to bring about immunity to the more virulent or fatal forms of the disease.

The introduction of vaccination by Jenner, in the year 1798, is the first instance of the production of immunity by the induction of a condition different from the disease against which protection is sought.

I suppose it is scarcely yet decided whether cowpox is a separate disease, or merely a modification of the deadly smallpox; but, whatever be its exact nature, there is no doubt that it confers an immunity which is probably less complete and less enduring than that conferred by smallpox itself, whether spontaneous in its origin or induced by inoculation.

From the splendid results of vaccination, attention was readily directed to the production of other diseases in a modified form, with the intention of affording protection from the virulent forms of the diseases. The ingenious and far-reaching mind of Pasteur, whose name will long remain the greatest in this line of research, was the first to bring into actual use the principles suggested by vaccination. It was in the disease of fowls, usually called fowl-cholera, that Pasteur first succeeded in producing artificially a vaccine, or, as he called it, an "attenuated virus." This disease is due to a small rod-shaped microbe or bacillus. It is cultivated artificially in glass vessels in the usual way, and, when inoculated in fowls, it produces an acute febrile disease, invariably fatal in one or two days. The bacilli are found in enormous numbers in the blood. It was found that when cultures of this microbe were left growing in glass for a long time, their virulence diminished greatly, so that when inoculated into fowls, the result was only a local and temporary disease, which the animals readily got over. And now, when fowls so treated were inoculated from a culture of full strength, they were found to be immune. Here, then, was an attenuated virus which acted like vaccine, in respect that a trivial and local affection afforded protection from a virulent and general one. Since these fundamental observations, which were published in the year 1880, a considerable number of infective diseases have, by various methods, been made to afford vaccines or attenuated viruses. Amongst the principal of these are anthrax, tetanus, diphtheria, hydrophobia, and cholera. The attenuation of the virulence has been attained in a number of different ways, besides that which Pasteur used for fowl-cholera. Thus, the mere cultivation artificially *in vitro*, if carried through successive generations without passing the microbe through the body of a susceptible animal, causes, in some instances, a diminution in virulence. On the other hand, a modification is in some instances produced by inoculating the microbe into an animal which is not very susceptible to that form of disease. Thus, in a disease of swine, called swine-erysipelas, which is induced by a small bacillus, a modified form of the virus is obtained by inoculating rabbits and using the microbes obtained from the bodies of these animals. This may be used to produce immunity in swine to the virulent form of the disease. Other methods which have been successfully employed are (1) drying for a longer or shorter period, as in the case of hydrophobia; (2) cultivation at higher temperatures, as in the case of

anthrax, or at lower temperatures; and (3) the application of various chemical agents to the cultures before inoculation. These various results, to which I can only make the barest reference, you will recognise as the products of much diligence and ingenuity during the last fifteen years.

Of late a most interesting advance in our knowledge of the subject has been made in the demonstration of the fact that in the induction of immunity by the methods referred to, the necessary element is not the microbes, but their toxines, and that the microbes are quite unnecessary if their toxines can be obtained separately. I confess that, for myself, I was unprepared for this result, which reduces the matter of acquired immunity to a question of the action of poisons. The toxines are separable from cultures of microbes by various methods. It may be done mechanically by filtering through unglazed porcelain, or the microbes may be killed by means of heat, or by an antiseptic, such as carbolic acid. If this be done in such a way as not to alter the chemical character of the toxines, then the symptoms of the disease may be induced by injecting the products into the bodies of animals. You do not in this way produce the disease proper, as its infective character is gone with the absence of the microbes. You reduce the matter to a mere question of administration of a poison whose dose can be regulated. Beginning with small doses of the toxines, and gradually increasing them, a state of immunity to the larger doses can be induced, just as, when the habit of morphia drinking has been established, almost incredible doses of that drug may be taken with impunity. Animals rendered immune to the toxines in this way are also immune to the disease; that is to say, they are no longer accessible to the infective agents, and the most virulent forms of the microbes may be inoculated without result.

It is interesting in connection with these results to point out that immunity to other poisons is producible by similar means. The poisons of the cobra and rattlesnake have some resemblance chemically to some of the toxines produced by microbes, and immunity to these snake poisons may be induced by progressive dosage with the poisons. The same applies to the vegetable poison ricin, obtained from the castor-oil bean, and abrin, from the jequirity berry.

A still further, and even more unexpected, advance has been made in the discovery of what are commonly called antitoxines. When an animal has been rendered immune, either by using the

infective microbes or the toxines, then it has been found, in the case of certain forms of disease at least, that the blood of the animal contains something which can be imparted to other animals so as to render them similarly immune. It is not necessary to use the blood as a whole. After some blood has been taken, it is allowed to form a clot, which, by contracting, squeezes out a clear fluid, called the serum of the blood, and this fluid contains the antitoxine, so that when injected, in relatively small amounts, into the bodies of animals of whatever species, it renders them immune to the particular disease concerned. This has been fully established in the case of two deadly forms of disease—namely, tetanus and diphtheria, and the results have been applied to the treatment of these diseases. In the case of diphtheria the procedure may be briefly described as follows:—The horse or the goat is selected, by preference, in order to obtain a supply of the serum. By a series of inoculations, either of attenuated cultures of the microbe, or of the toxine, in progressive doses, extending over some months, the animal is rendered absolutely immune to the most virulent cultures of the microbe of diphtheria. The animal so treated is bled so as to obtain some of its blood; the blood is allowed to coagulate, and is then left till the serum separates from the clot, and the serum can now be used for injecting into other animals, so as to protect them from diphtheria.

There is, again, a further stage in the evolution of this subject which is of the highest interest. The antitoxine in the blood serum not only protects the animal when injected into its body, but it produces its effects when applied to the cultures directly. Cultures treated with the antitoxic serum are rendered innocuous, so that the antitoxine exercises its effects whether it meets the toxine inside the body or outside.

Now, it is not my business here to discuss the utility of these important discoveries in the treatment of disease. There can be no doubt of the facts attested consistently by a large number of observers of different nationalities. If the antitoxic serum can be administered to an animal at the time, or soon after the application of the infective agent, then the animal will recover, although an otherwise fatal amount of the virulent microbe has been administered. In the human subject the antitoxine can never be given at the time of infection, and, indeed, can only be administered when the symptoms show that the disease is established. It must be matter of careful observation to what

extent the serum can effect the purpose after the disease has begun, and to what period of the disease its influence may extend. The case of tetanus is a somewhat peculiar one. The tetanus microbe is, as we have seen, introduced into wounds along with dirt carried in by the article which inflicted the wound. The microbe grows locally, but produces little or no disturbance in its local seat. It evolves its toxine, which, entering the blood, is carried throughout the body, and so reaches the nervous system, where it acts with extraordinary potency. The first symptoms, being those of irritation of the nerve centres, already proclaim that the poison is in the blood, and has begun its work. It is scarcely to be expected that, in this case, the administration of the antitoxic serum will be generally efficient. At the same time, its prompt application is said to afford some hopes of recovery.

It is different with diphtheria. In this disease, also, the microbe has a local seat, usually the parts about the throat, and it produces its most serious results by means of its toxine, which is carried into the general circulation. But the toxine produces important local effects, in respect that it sets up an acute inflammation in the parts mentioned. From this fact it results that comparatively early warning of the occurrence of the infection is given. Indeed, the condition of the throat may attract attention before any of the symptoms of general poisoning have developed. In this disease we may therefore reasonably expect better results from the use of the serum containing the antitoxine than in tetanus. The results of treatment are not as yet fully determined, but certainly there is very good promise of usefulness in this very fatal disease. It will be clear that an early diagnosis and an early application of the serum-treatment are essential, if success is to be obtained. It will be understood also that the treatment is used with great efficiency as a preventive measure in the case of persons exposed to the infection, as of members of a family in which diphtheria has broken out.

If, now, we look closely at the facts relating to induced immunity, we shall see that we have to deal with something quite different from natural immunity. We saw reason to believe that in natural immunity we have the more or less direct opposition of the living cells to the invasion of the infective microbes. Whether by phagocytosis or by some other method, the cells nullify the microbes, and so hinder the establishment of the disease. In the

case of induced immunity, on the other hand, it is essentially a case of the products of the microbes, the toxines; and the microbes come in in a kind of secondary way. This kind of immunity is, in the first place, an immunity to the poison—an acquired tolerance of it, as may be said. When we speak of a tolerance of a poison being established by repeated doses of it, we are in the habit of thinking of the living cells as becoming blunted in their sensitiveness to the poison; but that idea seems to be an incorrect one, and, so far as the toxines of infective diseases are concerned, it seems rather that, in their opposition to the poison, the living structures exercise a more active function. They produce agents which antagonise the toxines, and the whole process seems, in its foundation, an opposing action of the toxines and the antitoxines. In the prolonged process of immunising an animal, the cells of the animal seem to be stimulated to produce the antitoxines in increasing quantities, and these appear in the blood serum, by means of which they may be conveyed to other animals. It is true that the immunity, which is primarily an immunity to the action of the toxines, also extends to the infective microbes, so that, when these are introduced, they do not produce their usual effects. The explanation of this will be considered afterwards, but meanwhile we may safely infer that it is a consequence in some way of the immunity to the toxines which has been brought about.

It might appear from these facts that the whole matter is one of chemistry—the antagonism, in a chemical sense, of the toxines and antitoxines. It is a mistake, however, in considering the action of poisons, to regard the matter from the point of view merely of chemistry. It is, no doubt, in some aspects, a question of chemistry, but it is the complex chemistry of living structures. This subject can scarcely be understood without some reference to the nature and action of poisons in general.

The peculiarity of poisons is that, in minute doses, they produce profound effects on the living units of the body. The cells, which are these active units, are in themselves chemical laboratories, in which the processes are continually going on. The poison, sometimes in excessively small doses, enters into and deranges the intricate vital chemistry of the cell, and so interferes with its function. This is something very different from the mere reaction of dead chemical substances in a test tube. It is consistent with this that the poisons have what is called a *selective action*. Each

poison has not only a particular class of cells which it mainly affects, but the kind of effect varies in the different kinds of poisons. Thus, morphia selects the central nervous system, where it exercises partly a dulling and partly a stimulating effect. Strychnine also selects the nervous system, but concentrates its action on particular parts of it, where it produces intense irritation of the nerve centres. In their chemical nature the poisons are of various orders. We have the simplest mineral substances, such as arsenic; we have complicated alkaloids, such as strychnine and atropine; and we have albuminoids, such as the venom of serpents. The toxines of infective diseases belong chiefly to the class of alkaloids or of albuminoids.

The toxines of the infective microbes exercise their influence on the vital chemistry of the active cells, just as other poisons do, and they exercise their influence in similarly small doses. Those of tetanus and of diphtheria are toxalbumins, and hence, in their chemical constitution, they are related to that of the living cells, which are chiefly composed of albuminous principles.

As to the antitoxines, there are two possible ways in which they may exercise their protective influence. In the first place, they may, in some way, enter into chemical union with the toxine, as an acid does with an alkali, so as to produce a neutral or innocuous substance; or they may, in the intricate chemistry of the cell, exercise a protective influence by antagonising, in a physiological sense, the effects of the toxine. At first sight the former of these methods may seem the more likely. It is in favour of it, that, for example, when the antitoxine is added to the toxine outside the body, and the mixture is injected, the toxic effects remain absent. But, when we look more closely, this explanation becomes less probable. For one thing, the amount of antitoxine required to protect an animal seems to be small in proportion to the amount of toxine; and, for another thing, the amount of antitoxine required varies in the case of different animals, so that the same mixture will be poisonous in one animal and not in another. This scarcely looks like a case of chemical union or neutralisation. Moreover, an interesting observation by M. Roux, although it applies to the toxine and antitoxine of the venom of serpents, has evidently a determining reference to the case in point. When the toxine and the antitoxine are mixed before use, the venom fails in its effect, but, when the mixture is heated to 70° Centigrade, the virulence returns. It is as if there

were here two separate substances, one of which was altered or decomposed by a temperature of 70°, and one was not.

We may, I think, infer that the second of the foregoing explanations is the correct one, and that the influence of the antitoxine is on the vital chemistry of the cells, just as is that of the toxine, but in a contrary sense. This conclusion seems to me, also, the more probable in the nature of things. The antitoxine is a product of the active cells, and it seems more likely that it should be related to the chemistry of the living structures themselves than to that of a substance produced by absolutely foreign agents. This view is strikingly reinforced by the important observation that in some instances one form of antitoxine acts as a protective against a toxine to which, in its origin, it bears no relation. Thus, it has been pointed out by M. Roux that rabbits rendered immune to rabies are also immune to the venom of serpents. This can only occur, so far as I can see, by the antitoxine of rabies acting as a protective to the living cells, enabling them more efficiently to resist the toxine of the venom. It is no true objection to this view that the antitoxine exercises its influence when mixed with the toxine outside the body before inoculation, because, in that case, both agents are introduced, and the antitoxine protects the cells just as if it were introduced separately.

If, then, the processes concerned in acquired immunity are those of vital chemistry, how are we to bring these processes into relation with the microbes in the actual experience of disease? The animal which has been rendered immune is protected from the toxines, and we may justly inquire—what becomes of the microbes which are the natural agents of the disease, and which in the actual cases are introduced into the body of the animal? There is, I think, no reason to suppose that because the antitoxine affects the toxine, it therefore acts on the microbes. On the contrary, I shall mention a fact later on which seems to indicate that in some cases, at least, the presence of the antitoxine has little or no influence on the vitality of the microbes.

How, then, are we to suppose the microbes to conduct themselves when introduced into the body of an animal which has been artificially rendered immune by the antitoxine? Well, it is perfectly clear that the microbes are only of consequence to the body by means of their toxines, and if the action of the toxines is neutralised, then the microbes cease to be dangerous. It is possible, as already indicated, that the microbes may sometimes

proceed to multiply in the body in the presence of the antitoxine, but certain considerations render this unlikely, at least in most cases. The microbes of infective diseases differ from the ordinary forms, chiefly in respect that they produce toxines; but if they are deprived of the benefit of their toxines, then, I think, they may be relegated to the position of ordinary microbes. The toxine, in its local action, seems, as it were, to cover the advance of the microbes, and to give an opening for their multiplication. The living body in dealing with ordinary microbes by the means at its disposal, prevents them entering the tissues, and keeps them at its surfaces, where, indeed, they may be present in vast numbers, as in the alimentary canal and air passages. We may well suppose that the infective microbes, deprived of the advantages of their toxines, are similarly destroyed, or relegated to the mucous surfaces.

In order more fully to enforce what has been said, let us endeavour to picture to ourselves what the actual occurrences are—say, in the case of diphtheria,—first, in the process of rendering an animal immune, and next in cases where the serum has been used to protect a person on whom the infective agent has made its attack.

In rendering an animal immune small doses of the toxine are first administered, and these evidently stimulate the living tissues—that is to say, the cells—to the production of the antitoxine. With progressive doses the production of the antitoxine is augmented. It has been supposed by some that the antitoxine is, equally with the toxine, a product of the bacteria, perhaps even the toxine modified by the action of the living cells. This does not seem a probable view. The amount of antitoxine produced seems out of proportion to the toxine introduced. It is stated, for example, by M. Roux that it is possible from a rabbit immunised to tetanus to withdraw, by successive bleedings within a limited time, a quantity of blood equal to the whole blood of the body, and yet the serum will still retain to the full its antitoxic quality. The process of immunisation evidently stimulates the cells to the production of the antitoxines in increasing quantity.

And now, when this serum has been used to produce immunity in a person exposed to the infection of diphtheria, or in one who has already begun to show symptoms of the disease, let us consider what is the probable course of events. The microbe concerned in this disease exerts, by means of its toxine, a local as well as a

general effect. It mostly has its local seat in the fauces, where it sets up a violent inflammation, accompanied by a certain amount of death of the tissues, and an exudation from the blood. The microbe is found growing abundantly in these morbid products, and there seems little doubt that the result of the action of the toxine is to afford pabulum, and, by paralysing the tissues, to favour the growth of the microbe. But if the antitoxine has been introduced, then these local effects are warded off, and the microbe is relegated to the position of ordinary microbes, and may or may not remain on the surface of the mucous membrane of the part. There is no reason to doubt that the microbe may live on, without producing any symptoms, in the throat of a person who has survived an attack of diphtheria, or who has been rendered immune by the use of the antitoxine. This introduces a most important consideration in the preventive treatment of such diseases. I have been informed by an undoubted authority on the subject that, in the case of a boy at a public school who had passed through an attack of diphtheria and was perfectly well in health, he found in the secretions from the fauces abundant virulent diphtheria bacilli nine months after the attack. This is quite consistent with what I have been saying, and it is a fact of great practical importance which must be taken into account in all efforts to remove the infection of this disease.

In this connection, and as illustrating some other points in the relations of microbes to infective diseases, I may cite one or two facts in connection with acute pneumonia, or inflammation of the lungs. This disease is due to a microbe which has its local seat in the lungs, where it produces an acute inflammation, just as diphtheria does in the throat. Like diphtheria, its toxines, passing into the general circulation, produce those serious symptoms —fever, &c.—which form the most important features of the case. It is a curious fact that this microbe, which is capable of causing not only pneumonia, but likewise several other forms of acute inflammation, is frequently present in the sputum of healthy persons. This is proved by the fact that, when ordinary sputum is inoculated into rabbits, in a considerable proportion of cases it produces similar effects to those produced by the coccus of pneumonia, and this microbe is found in enormous numbers in the blood of the animal. This virulent microbe is present on the mucous surfaces of many, if not of most persons, but is kept, as it were, at bay. It seems as if, by circumstances affecting the

condition of the body as a whole, or perhaps of the lungs specially, the ability of the tissues to deal with the microbe were diminished, and it effects a firmer footing, and multiplies with extraordinary rapidity. It is also worthy of remark that at the point of time when a person with pneumonia "gets the turn," as it is said, the microbes do not suddenly disappear from the lungs, but are there virtually in equal numbers for some time afterwards. They have, almost suddenly, become innocuous, and the person goes on to recovery in spite of their presence.

And now, having carried you so far in the endeavour to comprehend a large subject within comparatively small limits, I should like to refer to one or two matters connected with the subject, one of which naturally arises in connection with what has just been said in regard to pneumonia. The facts relating to the production of the antitoxine go far to explain what has hitherto entirely baffled our comprehension—namely, the periodicity of certain infective diseases. How is it that smallpox, measles, scarlet fever, typhus, typhoid fever, pneumonia, diphtheria, and other diseases have a more or less definite period of time, at the expiry of which the symptoms gradually or suddenly subside, and the process of recovery begins? How is it, for instance, that in a case of pneumonia, you will one day have the patient in a high fever, breathing rapidly, and with an expression of extreme anxiety on his face, and the next day the fever has departed, the breathing is quiet, and the patient, though weak, is remarkably comfortable? In the condition of the lungs, which are the seat of the inflammation and the seat of the microbes, there is virtually no change, and yet the whole general aspects of the condition have altered.

The explanation is now perfectly plain. In the course of the disease a process of immunisation is taking place. The toxine, as it is produced and passes into the circulation, is, as in the artificial production of immunity, stimulating the living cells to the production of antitoxine. If the patient lives long enough for the production of antitoxine in sufficient quantity, then the action of the toxine ceases and the patient recovers. In the case of the several diseases which show this peculiarity of periodicity, each seems to have a particular time in which, on the average, the process of immunisation takes place, and so there are different dates at which the crisis occurs. When it does occur, then the toxine is neutralised in its action, and, although all danger is not past, as

the organs may be organically damaged by the attack, yet the danger of direct poisoning by the toxine is over.

The immunity so acquired in the course of the disease is that which we know to exist, and to last for some time, when a person has passed through an attack of one of the diseases referred to—the condition which at an early part of this discourse I distinguished as acquired immunity. It is consistent with these inferences that the diseases having a natural period for their activity are also those in which a single attack confers immunity, for a time at least, from further attacks. The two things legitimately hang together.

It is interesting also, in this connection, to consider the limits which we may expect in the application of the treatment by means of antitoxines. Wherever there is a disease which presents in the individual cases a definite periodicity, and in which a single attack protects from further attacks, then there is a likelihood that an antitoxine will be obtainable as soon as it is found possible to induce the disease in animals. We already hear of the treatment of pneumonia with antitoxic serum, and more recently typhoid fever has been brought under observation in this respect. Unfortunately, most of the periodic diseases still baffle observers in regard to the parasitic agents in their causation. As soon as the infective organisms are isolated, cultivated, and used successfully in animals, we may expect to obtain definite results by the use of antitoxines.

But there is a class of infective diseases in which, I think, we can scarcely look for any results in this direction. These are diseases in which the infection continues, and shows little or no tendency to a spontaneous cessation, and we may infer that in these there is no production of an antitoxine by the living structures of the animal. This applies to the group of suppurative diseases due to the ordinary septic microbes. A prolonged suppuration, in which the toxines are constantly absorbed and produce most serious general effects, can scarcely come under the control of antitoxines procured in the way in which those of diphtheria and tetanus are obtained. The same applies to the most frequent and most disastrous of all the diseases of mankind—namely, tuberculosis. This disease, in its various forms, goes on frequently for years, without any sign of the person acquiring immunity. The toxine of it is the well-known tuberculin, but there is no known antitoxine, and none is likely to be obtained on the lines

referred to. It is not that tuberculosis is a hopeless disease, even with our present knowledge, but that the way of cure is not to be looked for in this direction. As it is now made clear that the toxines are the potent and direct agents in producing the symptoms, and that these are capable of being antagonised by other substances, we may even venture to hope that there may yet be discovered some agents which will act as antitoxines to the diseases mentioned, although not procured in the manner which we have described.

In conclusion, I would merely allude to the intense scientific activity which the subjects we have been discussing have evoked during the few years easily comprehended within the life-time even of comparatively young men. Pasteur's original researches into the process of fermentation were begun about the year 1857, and were prosecuted during several subsequent years. Lister began his antiseptic treatment, which directly flowed from Pasteur's observations, in 1865. Koch's method of procuring pure "cultures" was announced in 1880, and created, in itself, an immense advance. Behring and Kitasato definitely made out the existence of antitoxines of tetanus in the year 1890, and it is since then that all the important researches bearing on this part of the subject have been made. You will admit that it has been a most interesting, and at times a most exciting, period for those interested in such subjects to have lived through.

IV.—*The History and the Results of the Operations of the Glasgow City Improvement Trust.* By Bailie SAMUEL CHISHOLM, Convener of the Improvement Committee. (*A Communication from the Economic Science Section.*)

[Read before the Society, 4th December, 1895.]

THE inception of the Glasgow City Improvement Trust was partly coincident with, and partly consequent on, that growth of public sentiment in the direction of sanitary and hygienic reform which has distinguished the second half of this century. The rapid and marvellous rush of population to our great cities, for which also the same period has been remarkable, found our municipal authorities all unprepared. Regulations and equipments, which might suit a town of moderate size within a few minutes' walk of the green fields and the sweet fresh breeze, became wholly inadequate in the altered circumstances which began to emerge. In Glasgow, as in all great centres of population, the following process might be seen at work.

On every side the fields are being absorbed by the extending town. Rural suburbs are swallowed up, and become in reality, if not in name, part of the growing city. The country track that ran between the city and its suburb becomes a busy, populous thoroughfare. And while this change is taking place in the outskirts, another, more fruitful of evil still, is going on in the heart of the city itself. The great majority of the houses which had any pretensions whatever had stood in the midst of garden ground. These pleasure gardens sloped to the banks of the Clyde, and of the limpid Molendinar, which flowed into it. These open spaces had done much to diminish the density of the population, and to provide ample breathing ground for the citizens. But the land was quickly becoming too valuable to be retained for such a purpose. Buildings of one kind or another were created where the gardens stood; not, be it remembered, under the guidance of any controlling authority, for no such authority existed, but simply as best suited the caprice or cupidity of the individual owner.

And beyond all this, and more disastrous still, another process was being carried on. Large and roomy houses of six or eight apartments, where wealthy merchants or comfortable burghers had lived, were deserted by their former occupants for more fashionable quarters, and a system of reconstruction and subdivision introduced, which resulted in six or eight tenants occupying in the one lobby the rooms which had together formed the accommodation of a single family. No Buildings Regulations Act secured light, or fresh air, or maintained for each sleeper a minimum of cubic space. In matters such as these every man was a law unto himself, and, when you add to all these conditions the primitive nature of Police Regulations in regard to nuisances, and, above all, the unsatisfactory character of the existing water supply of the city, the sanitary condition of Glasgow, bad as it was, was just what it might have been expected to be.

The old city, centring at the Cross, and radiating two to five hundred yards east, west, and north, together with the old burgh of Gorbals, across the river to the south, had become densely congested and frightfully unhealthy. There were narrow streets, with high and crowded tenements on either side; and closes, dark and filthy, running at right angles to the streets, were literally swarming with inhabitants. Within a comparatively narrow area 75,000 persons were huddled together, a large proportion of them under conditions which made physical well-being difficult, and moral well-being all but impossible.

In a paper, read before the Social Science Congress by the late Sir James Watson, the following description occurs:—"From each side of the Gallowgate, High Street, Saltmarket, Trongate, &c., there are narrow lanes or closes running like so many rents or fissures backwards to the extent of two, or sometimes three hundred feet, in which tenements of three or four storeys stand behind each other, generally built so close on each side that the women can either shake hands or scold each other, as they often do, from the opposite windows. When clothes are put out from such windows to dry, as is usually done by means of sticks, they generally touch each other. The breadth of these lanes is, in most instances, from three to four feet, the expense of the ground having at first induced the proprietor to build upon every available inch of it. Throughout the whole of these districts the population is densely crowded. In many of the lanes and closes there are residing in each not fewer than five, six, and even seven hundred souls, and in one close we

observed thirty-eight families occupying one common stair. In the Tontine Close there are nearly eight hundred of the most vicious of our population crowded together, forming one immense hot-bed of debauchery and crime."

One feature more of Central Glasgow forty years ago requires to be kept in view before the altered condition of matters can be realised in its due proportions. I refer to the number and to the character of the common lodging-houses which then existed. In the wynds and closes off the Trongate, as well as in the High Street and neighbourhood, there were scores of such lodging-houses, where many hundreds of poor creatures were crowded together in a manner that defies belief. The common decencies of humanity, not to say of Christian civilisation, were hourly outraged. The most elementary precautions against the spread of disease were neglected. There was no inspection by Police or Health Authorities. The sexes huddled promiscuously. Infectious diseases of virulent type were seldom absent, but there was no Fever Hospital save the Fever Department of the Royal Infirmary. There was no compulsory removal of fever patients, and when one unfortunate was removed to the Infirmary or to the grave, another lodger, surely more unfortunate still, occupied the same bed, and hugged around his person for bedclothes, the same meagre and infected rags. One result of all this was the prevalence of a death-rate simply appalling in its magnitude. In 1864 the death-rate of the whole city was 32·5. No statistics for the special district known as the Bridgegate and Wynds exist for that year, but even ten years later, when some amelioration had taken place, the death rate in the district was 48·2. In the days of the Terror, when the swift sickle of the guillotine was reaping its harvest of death, Vergniaud said, "The Revolution, like Saturn, is devouring its own children." Glasgow was, by a process less merciful than that of the guillotine, devouring her own children.

The Corporation of Glasgow was not the first to move in the direction of dealing in a practical manner with the evils which all were ready to acknowledge. The circle of municipal duties and obligations was then a more circumscribed one than, under the broadening influence of modern ideas, it has grown to be. But public spirit and true patriotism have ever characterised the community of Glasgow; and when it seemed as if, for all that officialdom could do, the great centre of the city might continue for ever to be the breeding place of disease and crime, the hot-bed

of pollution and vice, private philanthropy stepped in to do what private enterprise could, to lessen, if not to remove, the hideous blot from our midst.

A number of public-spirited citizens united for the purpose of purchasing property in some of the worst districts of the city, with the view of laying out wider streets and thereafter reselling the remaining building ground, or of themselves building upon it. Prominent among them stand the honoured names of John Henderson of Park, Lord Provost Blackie, Sir James Watson, James A. Campbell, and Sir A. O. Ewing. They made, however, comparatively little progress, their chief obstacle being the exorbitant prices demanded by holders of the ground, and the absence of compulsory powers to enable them to bring these parties to reason. But they did this service, they compelled public attention to the question; and their very failure proved that if the existing evils were to be dealt with at all, they could only be dealt with by a body to which Parliament would not be averse to commit the somewhat drastic powers which their experience showed would be necessary. After this a City Improvement Trust in some shape, and under some designation, became inevitable. Accordingly, in 1865, the Corporation appointed a committee to consider the question of a City Improvement Bill. At the first meeting of that committee Lord Provost Blackie, who was intimately acquainted with the whole history and failure of the private committee's efforts, expounded his ideas as to what was requisite, and during the autumn and winter of that year much arduous work in the maturing of a scheme was undertaken. The proposals of the committee do not seem to have met with any serious opposition either in the Council or in the city. The Bill, as introduced, passed smoothly through the various Parliamentary stages, and on 11th June, 1866, it obtained the Royal Assent.

The preamble of the Act set forth that "various portions of the City of Glasgow, and the buildings thereon, are so densely inhabited as to be highly injurious to the moral and physical welfare of the inhabitants, and many of the thoroughfares are narrow, circuitous, and inconvenient, and that it would be of public and local advantage if various houses and buildings were taken down, and other portions of the said city reconstituted." The Act appointed the Lord Provost, Magistrates, and Council of the city trustees to carry its provisions into effect. The trustees were authorised to enter into possession of all or any of the lands

shown in plans and books of reference which were deposited along with the Bill. These lands comprised the congested heart of the city, north, south, east, and west of the Cross, and a large portion of the ancient burghs of Calton and Gorbals, and of the districts of Oatlands (S.E.) and Overnewton (W.). One clause of the Act I desire specially to read, because it seems to me to answer fully the free and frequent criticism to which the trustees have been, and are, subjected in connection with the building operations. It is often said that we have departed in recent years from the purpose of the framers of the Act in building at all, and especially in erecting such premises as now adorn the south side of the Trongate, at the Cross. It is said that, if we are to build at all, we have no right to erect anything save houses for the poor, in order to accommodate the multitudes whom we have dispossessed. Now Clause XXII. enacts, "The trustees may take down the whole or any part of the buildings situated on any part of the lands acquired under the authority of this Act, and sell or dispose of the materials thereof, and may lay out the said lands of new, in such a way and manner as they may deem best, and may sell or dispose of the ground or buildings, or any part or portion thereof, or lease or feu the same on such terms, and subject to such conditions as they may fix, or *they may erect buildings thereon, and dispose thereof, or lease the same*, and, generally, they may deal with the lands, houses, and heritages acquired by them under the Act as absolute proprietors thereof, subject only to the conditions and provisions of this Act, and the Police Act for the City of Glasgow for the time being."

It is plain, therefore, that there was clearly before the minds of the framers of this Act, not only the contingency of erecting premises and letting them, but of erecting buildings other than workmen's dwellings, or, indeed, other than dwellings at all. Plainly, the men who were responsible for this Act realised that it might be necessary, and that it would be right, to erect buildings congruous to the locality and to the site on which they were to stand. I am not discussing at present the wisdom, or otherwise, of pursuing such a course. My point is that the Act contemplated it, and provided for it.

Another clause of the Act, which may be mentioned at this point, is that which authorised the trustees to provide for the north-eastern portion of the city a public park, and to expend in the acquisition and laying out of it a sum not exceeding

£40,000. Under this clause the lands of Kennyhill, on the north-eastern boundary of the city, were, in the year 1871, purchased and laid out, and as the net cost of these operations did not quite reach the maximum sum which the trustees were authorised to expend, they, with a handsomeness which seems to indicate that they believed they were in possession of a most prosperous estate, and that money was nothing to them, handed over to the Parks and Galleries Trustees, not only the public park now known as the Alexandra Park, together with 26 acres of feuing ground, all as authorised by the Act, but they also handed over to them the unexpended balance of the £40,000, which was the maximum sum they were authorised to expend.

The first meeting of the trustees was held on the 1st August, 1866. Of the fifty gentlemen who composed the Trust, only one remains still a member of the Town Council—the much-esteemed and loved Preceptor Osborne.

Energy of action was not lacking at the commencement of its work. Two committees were appointed—a property-purchasing committee, and a committee to carry out all the other provisions of the Act. To show the importance attached to its operations, the Lord Provost, who had always taken a very warm interest in the subject, accepted the convenership of both committees, and, more significant still, both committees were entrusted with full powers, except with regard to the assessment.

The first meeting of the Trust was held on 1st August, 1866, and on 6th September following—that is to say, within five weeks of its first meeting—the trustees fixed the assessment for the year at 6d. per £1 on the rental, being the maximum rate authorised by the Act, which likewise provided that the whole of the rate was exigible from the tenants. This decision brought home to the ratepayers what they had as a body barely realised—that the rooting out of the slums of a great and growing city could not be effected save at an enormous cost. They had been, with a mild self-complacency, congratulating themselves on the patriotic work in which their Town Council was about to engage, but they had done so all the more heartily that they honestly believed it would cost them next to nothing. They expected that the enhanced prices that would be obtained from ground in improved and widened streets would amply cover the loss sustained in making the improvement, and their surprise at the impost had in it all the keenness of a sense of wrong. The policy—that is to say,

the "politicness," of imposing the maximum rate at the very first is open to question, and its results were, to say the least of it, somewhat dramatic.

The Lord Provost, who had warmly espoused the policy of the Trust, had finished his term of office, but was willing to return to the Council, chiefly for the purpose of taking part in carrying on the improvement work on which it had entered. He offered himself for re-election, but the entire city was up in arms, and, in spite of his long public service and his high personal character, he was defeated at the poll. Lord Provost Blackie was succeeded, not only in the civic chair, but also in the convenership of the Improvement Trust Committee, by Sir James Lumsden.

As was to be expected, the first few meetings of the new Trust were deluged with motions and notices of motion in regard to the obnoxious rate. It was found impossible, however, to come to any decision until the cost of the operations in which they were already engaged had been ascertained, and the fixing of the rate was adjourned till the usual time—that is to say, after the close of the financial year. One aspect of the rate, however, which has been a standing grievance during all its history, cropped up at that early period, and was the subject of a special resolution. It was felt even then that a mistake had been made in causing the incidence of the rate to rest wholly on occupiers and one of the resolutions tabled, instructed the committee to "report forthwith the most expedient method of laying a fair share of the tax on property, including ground annuals and feu-duties." Though this resolution, along with the others to which I have alluded, was withdrawn, I need not say the committee have continually tried, but tried in vain, to correct the initial blunder.

Only three years ago the latest effort in this direction was made, by seeking to obtain Parliamentary sanction for dividing the rate, causing it to fall equally on landlords and tenants. The proposal was approved by the Committee of the House of Commons, but was rejected by the Committee of the Upper House. If the question has ceased to be a burning one, it is not that the principle involved has ceased to be accepted, but that the rate has fallen to so infinitesimal an amount that it is impossible to evoke any enthusiasm on the subject. It may, however, be safely predicted that in any future measure which the Corporation may deem it right to promote for the purpose of making public improvements, one marked effect of which will be to enhance the

value of lands held by private proprietors, very vigorous efforts will be made to prevent proprietors as a body, and especially those immediately interested, from reaping the pecuniary benefits of a scheme to the cost of which they contribute nothing. But I shall not be further tempted into the alluring subject of the principle of "betterment."

When, at the close of the financial year, the first balance sheet was presented, it showed many points of great interest. The rate of 6d. had yielded, in round figures, £38,000 (a similar rate to-day would yield over £80,000); loans had been contracted to the amount of £144,000; and the rents that had been received amounted to £1,500, a sum which did little more than pay the interest on the loans. The other side of the balance sheet showed that property had been purchased and paid for to the extent of £50,000, and that the Parliamentary expenses had amounted to more than £17,000. Of this latter sum it may be remarked, as illustrating the difference of procedure between now and then, that the Town-Clerks' charges for personal services and office expenses amounted to over £8,000, while another of the city officials received an allowance of £1,000. The unsatisfactory nature of this class of payment was doubtless one of the reasons why the Town-Clerks were sometime thereafter, by a special minute of the Trust, deprived of their secretarial and legal advisory position, and a gentleman wholly unconnected with the Corporation engaged at a fixed salary to discharge their duties.

Lengthened and acrimonious discussions took place in committee and in public in regard to the general action of the Trust, and in regard to the assessment for the following year. The committee's action, however, was approved, and their recommendation of a rate of 4d. per £1 for the second year was adopted. The next few years were years of extensive purchasing of property, averaging £200,000 per annum, so that the balance sheet of 1872 showed assets in lands and buildings valued at over a million sterling.

Demolition of purchased properties had taken place to a moderate extent, but the broad, comprehensive schemes of reconstruction of entire areas, which the committee had sketched, were postponed. The proceeds of the annual assessment were required to meet the annual expenditure. A sudden or serious diminution of the rental would necessitate an increase in the rate. That was an alternative scarcely to be faced in any circumstances. But the

Act itself provided that, while the maximum rate of 6d. might be imposed for the first five years, thereafter the maximum must not exceed 3d. A diminution, therefore, rather than an increase of revenue from assessment, was to be reckoned on. And so, whereever remodelling and rehabilitating of property could be accomplished, even though the result did not satisfy the ideas of the committee as to the general comfort or sanitary completeness provided, if it was an appreciable improvement on what had formerly existed, it was adopted, and the continuance of the rental was thus secured.

Had this action, or inaction, been accompanied by the appointment of one or more active and intelligent caretakers to supervise both the property and the tenants, and maintain as high a standard of cleanliness and comfort as was possible, it might have been justified. But the property was handed over to factors, of whom there were at one time no fewer than twenty-two. These men, while, I doubt not, discharging their duties with integrity and fidelity, could not be expected to enter into the spirit of the Trust, or the thoughts and hopes of its promoters. Naturally enough, their first thought was the maintaining of a good return to their employer. Repairs and improvements were delayed as long as possible, and, when executed, were kept down to a minimum, and the result was that in the course of years the property remaining in the hands of the Trust, and occupied by its tenants, was the worst and most insanitary in the city.

From this point forward it may be desirable to deal shortly with various divisions of the subject separately, and pursue each to its own conclusion. I wish, therefore, to call attention (1) to the new or greatly improved streets which the Trust provided; (2) to the lodging-houses which the Trust erected; (3) to the general building operations in which the Trust engaged; (4) to the financial aspect of the whole undertaking; and then close with a word on the present position and the immediate prospects of the Trust.

The new streets which the Trust has opened up are many of them on the site of crowded and most discreditable tenements. They number in all thirty, and include such well-known names as "Blackie," "Lumsden," in Overnewton; "Watson," "James Morrison," "James Moir," "Moncur," in the centre and east. Many of them have now become so familiar that we are tempted to think of them as belonging to Old Glasgow. But the widening, the straightening, and levelling of existing streets were quite

as important operations as the formation of new ones, and not less expensive. There must be many who remember the width of the old Saltmarket, and who can realise the contrast which it presented to the spacious thoroughfare which now bears its name. The unequal level of the western portion of the Gallowgate rendered it an inconvenient, not to say a dangerous, roadway, while the narrow lanes by which Ingram Street was continued to High Street, and by which South Albion Street ran up into North Albion Street, rendered through traffic in either of these directions all but an impossibility. These and many other similar localities have all been so dealt with that broad and level highways now invite and accommodate a vast traffic where formerly frowning tenements looked down on dark and narrow lanes. Into thirty new and twenty-six widened streets there have been thrown 100,000 square yards of ground, and estimating that at the very moderate average price of £4 per yard, and adding £100,000 which the Trust has expended in making these streets, we have half-a-million of money, which is as nearly as may be the amount which the citizens have contributed by means of the improvement rate. In this there is not included the ground thrown into the Trongate, by which that historic centre of the city is broadened out into a magnificent and imposing *place*, with the general appearance and character of which it is to be hoped the new station of the Caledonian Railway Company at the Cross will harmonise. No credit is taken by the Trust for this widening of the Trongate, inasmuch as it was done at the instance and cost of the railway company.

The model lodging-houses which the Trust has erected were forced upon it by the discoveries made by its members in the course of that personal visitation of the properties purchased, which distinguished the earlier, as well as the later, years of the undertaking. Many hundreds of men and women were found to be living in such lodging-houses as I have already described. Many of these persons never desire to become householders. They desire no care when the work of the day is over. That may be, or it may not be, wrong and unworthy, but it is true, and the questions which the Trust had to face when the frightful condition of existing lodging-houses (many of them in their own property) came home to them were—Is it *our* duty, as a Trust, to do anything to remedy the appalling evils of these dens of filth and vice? and, if so, what can we do? I believe the answers which the

Trustees gave to both queries were wise, and have been amply justified by the results. They felt it impossible to shake off responsibility. And they further believed that the closing up of the lodging-houses in their own property would only drive the keepers into other property where less supervision would take place; and to enforce rules and regulations would be far less effectual, if it were not accompanied by an object lesson showing how the thing could be done. Accordingly, in 1870, two model lodging-houses were opened—one for men in Drygate, and one for women in East Russell Street, Calton. These were followed, in subsequent years, by others situated in various parts of the city, so that now the Trust owns seven lodging-houses, with accommodation for 2,200 lodgers. In these homes each man or woman, as the case may be, is provided with a separate cubicle. He has the use of a kitchen where utensils are supplied, in which he may cook his food at a hot-plate, which is always in condition. A commodious dining room is provided, and a large and airy recreation room. Ample bath and lavatory convenience is at his disposal, and accommodation where he may wash and dry his own clothes. He has the run of the home for 24 hours for a sum varying from 3½d. to 4½d., according to trifling differences in the sleeping accommodation. In regard to the sleeping accommodation, it may be remarked that the cubic space per sleeper in the earliest lodging-house was 331 feet. This has been increased by subsequent alterations, and in the recent extension to this home the allowance per sleeper is 384. The latest addition to Portugal Street Home gives 412 feet, while in the new home in Moncur Street there is provided for each a space of 435 cubic feet.

The erection and maintenance of these lodging-houses, I have no hesitation in saying, have been a great and, I had almost said, an unmixed blessing to the poor, and, I must add, in many cases, the thriftless and forgetful class who frequent them. Granted that they often are guilty of all, and more than all, the sins and follies with which their severest censor can charge them, is that a reason why they should be housed in filth, and subjected to all the demoralising influences of gross indecency and vice? It is said we tempt men to run away from their wives, and *vice versa.* I reply, it shows little knowledge of human nature to imagine that the attractions of a model lodging-house will make a man desert his wife. He deserts her, if at all, for far other reasons, into which I need not inquire. But even if such cases were far more

numerous than I believe they are, all that the model lodging-house does is to say, if a man does desert his wife for reasons good, bad, or indifferent, I object to his being, on that account, permitted or compelled to lodge in circumstances that are a menace to health and morality. The Corporation lodging-houses have done far more than provide comfortable accommodation for their own residents. They have set up a standard of comfort to which others have been compelled to conform. And now, under the combined influences of this healthy rivalry, and of more stringent sanitary regulations, the old pestilential lodging-houses have disappeared from our midst.

The latest, and, in some respects, the most interesting, addition to the Trust's lodging-house enterprise is that which, though not yet completed, has already attained considerable notoriety as "The Family Home." This is not a home, as many seem to think, in which thriftless, careless fathers and mothers are to be relieved of all responsibility for their children, and allowed or invited to throw the care of them over on a maternal Corporation. It is an effort to enable a most deserving class to do better for themselves and their children than without such assistance they could possibly do. If one were asked, what class of the community is the most helpless, and stands most in need of guidance and aid, I am sure a very little consideration would suggest this to many as the most likely answer: it is poor labourers who have lost their wives, and have three or four young children, or poor widows who are similarly left. Just think what these people have to do. To go out at five or six in the morning is nothing in itself, but then what about their own food, and especially what about their children? Are they to be locked in, or locked out, or left their own masters with an open door? The man may get some woman to look after his children, but all he can afford to give her is such a trifle that in many cases the woman is unsuitable, and proves a curse both to him and his children. Then, when the man comes home, or, to turn to the other sex, when the widowed mother comes home, worn out with a day's charring, or some such employment, is it reasonable to expect her to begin and scrub out her house, take her turn at the stair, and attend to all the demands which our modern police regulations properly make? To expect all that is to expect the impossible, and the condition of Glasgow and Glasgow poor to-day is to a large extent traceable to the unreasonable burdens that are laid on such shoulders, already overtaxed.

The Family Home is designed for widows, or for widowers with young children. It consists of 160 single rooms, each capable of accommodating one adult and three children. Each room is isolated, plainly furnished, heated with hot water, and lit with electricity. The cleaning, therefore, will be reduced to a minimum. The children will be taken charge of during the day—those of them of school age will be sent to school, those under it will be taken care of in the Home, where a crèche, a general recreation room, and a cooking and dining room are all provided. It is not meant to be a charitable institution. Each resident will pay a daily charge, to cover the rent of the room and the care of, and food for, the children. The Family Home is meant to help those who seem to need it most, to spend their little earnings to the best advantage for themselves and for those dependent on them. The committee are at present in search for a matron-superintendent, and they keenly realise that much of the future success of the home depends upon the wisdom of the selection which they may make.

A word or two may now be said on the Trust's building operations. Though amply provided for in the Act of 1866, building operations were doubtless regarded by the promoters as a *dernier ressort*, to be adopted only as an unwelcome alternative. But when stances, which had been cleared of all buildings, were being but sluggishly taken up by builders, and that at prices in many cases far under what had been paid, and under what was believed to be present value, the question naturally became a burning one, Shall we force our ground on what seems to be an unwilling market, or shall we ourselves build? One or two trifling experiments, proving nothing, had been made in earlier years, but in 1888, after long discussions, and with fear and trembling, Block No. 1, east side of Saltmarket, corner of Steel Street, was begun. This was followed by Block No. 2, to the north of No. 1, and thereafter, but specially during the last four years, there have been erected, on vacant ground in some cases, and on the site of ruinous and disreputable tenements in others, buildings consisting of shops and dwelling-houses at a cost of £125,000,

Exclusive of tenements that are at present in course of erection in Kirk Street, Calton, Saltmarket, and neighbourhood the Trust owns considerably over a thousand dwelling-houses, accommodating a population of nearly 6,000. The entire property is superintended by a general manager, who has under him two caretakers. These

latter visit regularly and frequently the household property, and see that it is kept in a condition of cleanliness and comfort, and that one or two careless or ill-behaved tenants are not allowed to destroy the peace of the tidy and well-doing.

It has to be acknowledged that until quite recently the Trust did little in the way of erecting cheap dwellings for the very poor. Two explanations may be offered of this admitted fact. First of all, it was thought that a fair, if not a sufficient, provision for this class was already in existence; and, in the second place, the localities in which the alternative of building was first forced upon the Trust were so situated that cheap dwellings were an impossibility, no matter how low the cost of the buildings might be, owing to the price of the ground. But latterly, when the more clamant cases of Saltmarket and Trongate have been dealt with, the Trust has addressed, and is addressing itself, in Rottenrow, and St. James' Road, Stobcross Street, Kirk Street, and Cumberland Street, Calton, to the providing of comfortable and sanitary dwellings for poor people, at an annual rent of from £4 10s. for a well-equipped single room, upwards.

It would be unfair if I did not acknowledge that, so far as the majority of the Improvement Trust Committee are concerned, this building policy, which may at first have been regarded as a questionable experiment, has come to be accepted as a justifiable, if not a preferable, alternative, not only to that of allowing it to remain idle, but even to that of feuing it for building purposes to others. I presume there will be no doubt in any quarter as to its being better for the Trust to build than to allow its land to lie idle and unremunerative. But how justify the preference for the Trust building on its own account rather than feu to others for the same purpose? It is, perhaps, a somewhat delicate matter for any single member to answer that question, inasmuch as neither the committee nor the trustees have ever come to any formal declaration on the subject. But gathering up the opinions that have been expressed in the course of many discussions on individual cases, I may say the reasons are practically two in number. First of all, it is said there is a large class of respectable but poor householders, who, if left in the matter of house accommodation to the remorseless law of supply and demand, could not afford to pay the rent exacted for such conveniences as they require. They would be compelled, therefore, to content themselves with a condition of things in which neither the demands of health nor decency were complied

with. The Corporation, having the land in its possession, and being able to borrow money at a low rate, and not requiring to pay dividends or profits, is able to supply a higher standard of comfort and convenience at a lower rental than others can. And it is argued that the Corporation is only discharging its duty to the humbler class of the citizens when it offers them this supply to the extent of its power.

The other reason is to be found in the undesirability of the Corporation parting with its land at all, save for very important exceptional purposes which could not well be served if it continued to hold it. I need not tell this audience that land is not an ordinary commodity, like cotton, or iron, or sugar. The possession of land is the monopoly of the world, and its pressure is specially felt in this country to-day. Most of all is its pressure felt in our extending towns and cities. A prolific or a scanty harvest of commodities in any quarter of the world may make the values of these, be they grain, or fruit, or wool, rise or fall, and, to a certain extent, the value of agricultural land in remote districts of the country may be for a time affected thereby, but in a growing community the value of the land on a series of years is only and ever rising. I need offer neither instances nor proofs. In these circumstances, why should the Corporation of a city like Glasgow, with its ever-extending municipal enterprises, sell to-day, or this year, any of the comparatively little land it holds, only to throw the increment, which is sure to accrue, into private coffers, or, perhaps, even to have to buy it back to-morrow or next year at a greatly enhanced price?

This latter contingency is no chimerical fear. In the prosecution of the sewage scheme on which the Corporation has embarked, it will be necessary to have a pumping station for the low-lying lands in the west of the city and of Partick. Fortunately the Corporation owns a piece of land on the banks of the Kelvin admirably adapted for the purpose, valued at a moderate price. It is absolutely certain, had we parted with that land a few years ago that we would have had to purchase it, or some other portion, at a greatly enhanced cost. Our Sanitary Department is at present erecting new chambers in Cochrane Street. The ground belonged at one time to the Corporation. In 1786 the city disposed of it for a cash payment of £58 2s., and a yearly feu of £2 18s. 1d. For the purposes of the Sanitary Department the land had to be bought back again, and the city took it over, burdened with the

feu, at the slump price of £11,450. The ground in George Square, on which our municipal buildings stand, was at one time also in possession of the Corporation. In 1786 it also was sold for a cash payment of £403 6s. 8d., and a feu-duty of £20 3s. 4d. When it was required by the city, it could only be redeemed at a cost of £172,953 12s. 10d.

On purely economic grounds, therefore, it may fairly be contended that, while it is the duty of the Corporation to see that the land it holds is put to the best possible use, it is not in the interests of the city that it should, in ordinary circumstances, allow that land to pass into the ownership of others. That in other aspects the building operations of the Trust have been of great advantage to the city, everyone will acknowledge, who, remembering what King Street and Princes Street, City, were, will take the trouble to see the area embraced by Parnie Street, King Street, and Osborne Street to-day. But it is said by some that all we have done has been to drive the vicious and criminal population, which we formerly accommodated, to other quarters of the city, there to shed abroad the same malign influence. That statement may be dealt with in many ways. I give it the one reply—that it is not true. That is *not* all, or nearly all, that we have done. Formerly we not only housed these people, we bred them. The maintenance of the old dens made the continuance of these people a necessity. In sweeping these breeding styes of vice clean away, we have given healthiness of body, and purity or decency of life a chance, which formerly they had not. We have set an example by which, if other proprietors would follow—the proprietors, for example, of the west side of King Street, City,—the social and domestic amenities of our poorest citizens would in a very few years be vastly improved.

A word or two must suffice for the financial aspect of the undertaking, although it would have been easy to have dwelt on it at great length. The Trust has expended on the purchase and im-

provement of lands and buildings, ...	£1,955,506	19	4
On the erection of buildings, including lodging-houses, ...	231,479	12	8
Making a total of	£2,186,986	12	0
It has sold or created feu-duties to the value of	1,072,680	0	0
Leaving balance, ...	£1,114,306	12	0

Brought forward, ...	£1,114,306 12 0
The heritable property of the Trust, exclusive of its feu-duties, is valued at	691,161 18 5
Showing a deficiency of	£423,144 13 7
The total cost of the undertaking to the ratepayers during these 30 years has been	593,079 16 6

against which have to be set the Alexandra Park, 100,000 square yards of ground thrown into streets and squares, and the sum of more than £100,000 expended in forming the streets, and in covering the Molendinar and Camlachie Burns. The charge against the ratepayers may now be said practically to have ceased. Last year the rate was ½d. per £1 of rental, and the operations of the Trust were for the first time in its history self-supporting, so that the entire amount the assessment yielded was carried to the credit of the valuation at which the property stands in the books. During the current year the rate was, as a precautionary measure, continued, but at the reduced amount of a ¼d., so that, while it would be premature to make any promise, it is plain we are within sight of its entire abolition. Any surplus which may then accrue will doubtless be for some time carried to the credit of the valuation account, which is practically to the formation of a sinking fund.

The lodging-houses have from the very beginning yielded a revenue over the yearly cost. The gross cost of the seven lodging-houses, including the price of the ground, has been £103,258 18s. 1d., and on this amount, in addition to writing off as depreciation the sum of £11,232, there has been a yearly return averaging from £3 14s. 9d. to £6 11s. per cent. In regard to the financial results of the various building operations, it would be not only tedious and uninteresting, but misleading, to give them in detail. Unfortunately, through no fault of our treasurer, the City Chamberlain, the statement of these various operations has not been made on an identical basis. Sometimes there has been no charge for ground annual, and then the return seemed to be large. In other cases, a ground annual was charged based on a cost much higher than the ground would bring in the market, and there the return seemed to be small. These anomalies the committee is at present engaged endeavouring to remove. But, in the meantime, it may be broadly stated that in every case we have received full interest for all our outlay—that is to say, larger interest than we have paid; and at the same time we have received, in addition,

a larger return for the ground than we could have obtained by selling it, while in many cases we have made a revenue out of ground which was yielding no return at all.

The Trust has still some work before it. It has set itself to turn to the best account, in the interest of the citizens at large, the property with which it is invested. The committee realises that the original Act of Parliament imposed a serious responsibility on the Corporation. That responsibility is not discharged until the estate with which that Act of Parliament permitted it to invest itself has been fully developed to the moral and social advantage of every section of the community.

V.—*Why has England become a Great Manufacturing, Commercial, and Colonising Country?* By RICHARD LODGE, M.A., Professor of History in the University of Glasgow.

[Read before the Society, 18th December, 1895.]

THE subject which I propose to treat this evening is really too large for a single address, and would require a course of lectures to bring out its full significance. I cannot, therefore, attempt to say anything new or original, or to add to the stock of human knowledge on the subject. I must content myself with endeavouring to put before you, as briefly and as clearly as I can, some of the most obvious and important of the causes which made England, and later, Great Britain, take such a prominent part in manufactures, commerce, and colonisation. A Scottish audience may possibly cavil at the use of the term "England" in the title of my paper. In defence, I can only plead a pedantic love of accuracy, in that some of the most powerful forces which I have to describe came into operation at a time when England was not only distinct from Scotland, but was also in great measure hostile to its northern neighbour. The term "Great Britain" has its meaning and its place in history, and I am informed that an association has been formed in America to advocate its use upon all occasions. But it is important to remember that "Great Britain" suggests unfortunate exclusions just as much as "England," and that the term must be carefully avoided when its use would be both incorrect and misleading.

Most people who had not given special study and consideration to the subject, if asked to account for English success in manufactures, commerce, and colonisation, would probably reply that the secret was to be found in (1) national character, and (2) our insular position; and such an answer would to some extent be correct. The geographical position of England, its coast-line and

harbours, and its relation to the great trade routes of the world, have undoubtedly had a vital influence upon English development; and the national characteristics, both of Englishmen and Scotchmen—if we can agree upon their definition, which is no easy task, —have equally had their share in stimulating the growth of industry and trade, and notably in effecting the great triumphs of colonial expansion.

But a moment's retrospection will be enough to show that this answer is, to say the least, incomplete. Britain was an island in the fifteenth century as in the nineteenth; and the national character—so far as it is innate, and not developed to suit the nation's circumstances—was much the same then as now. Yet England, as late as the fifteenth century, was by no means distinguished in manufactures, or in commerce, or even in maritime adventure. On the contrary, mediæval England was pre-eminently an agricultural country. The energies of the great bulk of its population were absorbed in the raising of food and in the production of wool for exportation. The foreign trade of the country was almost wholly in the hands of foreigners, either of the Germans, who were organised in the great Hansa of London, or of Italians, who added to their mercantile business that of banking and money-lending. Even the fisheries, so lucrative an industry in the Middle Ages, were for the most part left in the hands of the Dutch, Swedes, and Norwegians. It is true that, at the close of the Middle Ages, some progress was being made by native energy. In the fourteenth century we can trace a prolonged struggle of the English burghers against the privileges enjoyed by foreign merchants under the interested patronage of the crown. The introduction of Flemish artisans into Norfolk, under Edward III., marks the first step in checking the exportation of wool and in starting the home manufacture of worsted and cloth. In the fifteenth century the Society of Merchant Adventurers, "the parent of all the later trading companies, which won for England her commercial supremacy," became the rivals of the Hanse traders in northern Europe. The vigour of these adventurers broke down the restrictions imposed by the mediæval institution of the Staple, and after a long struggle against the traditional monopoly of Flemish manufacturers, the Great Intercourse of 1496 secured the admission of English cloth to the markets of the Netherlands.

But this progress, though significant and important, was in no

way phenomenal, nor was it at all comparable to the extraordinary advance made by England in the sixteenth and seventeenth centuries. For the novel development, which changed the whole face of England and the whole character of its history, we must find an explanation in the great "agrarian revolution" which gives to the Tudor period its unique importance in the annals of England. The social change then effected was so many-sided that it is difficult to express it in a short compass without inaccuracy. In the Middle Ages land in England, as throughout Western Europe, was held on what is called feudal tenure. The differences between this system and that which prevails in the present day are almost innumerable. The unit of cultivation was the manor or village. The lands of the manor consisted of the lord's domain, of the lands of the free tenants, and the lands of the servile tenants or villeins. There was no private property in land as expressed in the right of arbitrary eviction. The lord held of the king on condition of performing certain services. As long as the conditions were fulfilled, the lord's rights were protected by law. So the free tenants owed services to the lord, from the military service of the knightly tenants to the payment in money or kind of the free socager, but as long as the service was performed or the rent paid, the tenant enjoyed fixity of tenure. Even the villein or serf, who, in return for his small holding, was bound to labour so many days a week on his lord's domain, was protected in his occupation by custom, if not by the letter of the law. Land in such a system was not regarded so much as a source of revenue, but rather as a basis of mutual rights and duties. The modern idea of competition was almost entirely absent. There were land-*holders* rather than land-*owners*. And the lands thus held were not collected together in contiguous holdings, as is now customary. Not only the lands of the villeins and free tenants, but often the lord's domain, were scattered in small strips over the large arable "fields" of the manor. The pasture was subject to rights of common except during the period of the hay harvest. Even the arable land was frequently open for rough pasture after the yearly harvest had been reaped.

The same or similar conditions existed in most European countries, and in all they gradually disappeared. In England this disappearance was more rapid than elsewhere, and the process had peculiar characteristics and results. The first beginning of the change was seen in the gradual substitution of money payments

for the old labour services of the villeins. As long as population continued to increase in a normal manner, this process continued to go on without attracting any special notice. It was for the most part to the mutual advantage of lord and vassal, and if it had had time to work itself out, it would have produced a class of small peasant tenants, each working his small holding for a customary rent, and passing it on to his heirs at his death.

But this peaceful and gradual development was interrupted in the middle of the fourteenth century by the Black Death. From a third to a half of the population perished of the plague. The economic results were immediate and far-reaching. The lords had no longer enough villeins to cultivate their domain, and when they tried to supplement them by hired labour, they found that wages had risen to an amount undreamt of before the pestilence. Their immediate impulse was to repudiate a bargain which was suddenly found to be disadvantageous, and to claim the old services from the peasants, who had been allowed to commute them for a sum of money, which, under the altered circumstances, was no equivalent to the lord. At the same time the landlords made use of their ascendancy in Parliament to pass statutes fixing wages at the amount that was customary before the Black Death. These efforts were unsuccessful, but they served to excite bitter and general discontent, and this discontent was one of the most potent causes of the great rising of 1381, which is popularly associated with the name of Wat Tyler. The rising itself was suppressed, and its chief result was the panic which it caused amongst the upper classes. But there can be no doubt that economic forces were on the side of the peasants, and on the whole they gained the upper hand in the last half of the fourteenth century. They kept their holdings. They paid little more than the old customary rents, while the high wages which they could gain for extra labour enabled them to pay these rents with ease. At the same time their success, coupled with other circumstances, improved the lot of those who still owed the old villein services, and who had been, perhaps, the chief sufferers from the plague. There was no sudden abolition of villeinage in England, but there can be little doubt that the half century which followed 1381 witnessed a very great acceleration in the process of emancipation.

We may sum up the success of the peasants with sufficient accuracy by saying that they vindicated a right of property in

their own labour. But they thereby broke the implied compact which lay at the bottom of a healthy feudal system. Sooner or later the lords were almost sure to follow the example of the labourers, to repudiate the claim of the tenants to a legal right of occupation, which had been either tacitly or formally acknowledged under other and now obsolete conditions, and to claim for themselves a right of property in the land. This was the change which was going on in the latter part of the fifteenth and the first half of the sixteenth centuries. A large number of circumstances combined to bring it about. A sweeping change in the holders of the great estates was commenced by the Wars of the Roses, continued by the Yorkist and Tudor executions, and completed by the dissolution of the monasteries and other corporations under Henry VIII. and Edward VI. The new lords had no personal ties with their tenants, nor any of the good feeling which usually results from ancestral connexion. They had risen, for the most part, from what we should call the middle classes—from the lawyers or merchants,—and they brought mercantile ideas and associations into their dealings with the land. If they let it out to others, they would exact the highest possible rents; if they farmed it themselves, they would adopt the most profitable method of cultivation, and they soon perceived that it was far more advantageous to raise wool than to grow crops, and that pasture was much more advantageous than tillage.

The first sign of the altered conditions was the growth of the practice of enclosure, which extinguished most of the rights of common enjoyed under the manorial system. Not only did the lords enclose their domain lands, but the tenants, for the most part, hastened to follow their example. By mutual agreement they enclosed their separate strips of arable and pasture, and put an end to the rights of common over each other's land. By exchange of strips, holdings were to a great extent concentrated, though traces of the old scattered holdings survive in many places to the present day. Thus the agrarian partnerships of the Middle Ages were broken up, and the idea of private ownership or occupation took the place of the feudal idea of joint occupancy.

But enclosures were not enough to satisfy the desire of the landholders for large sheep-runs. The holdings of the smaller peasants were an obstruction to the new scheme of cultivation. This obstacle could only be removed by eviction, and eviction was generally resorted to. The agrarian revolution was accomplished with a

complete regard of rights which, in earlier times, had been respected, even if they had not been recognised by the law. The evidence on the subject is both plentiful and conclusive. The preambles to the Tudor statutes, the sermons of Latimer, the "Utopia" of Sir Thomas More, are full of complaints of the substitution of pasture for tillage, of the evil results of the change, and of the harshness with which it was effected. Bacon, in his "History of Henry VII.," says:—"Inclosures at that time began to be more frequent, whereby arable land, which could not be manured without people and families, was turned into pasture, which was easily rid by a few herdsmen, and tenancies for years, lives, and at will, whereupon much of the yeomanry lived, were turned into demesnes." A petition under Henry VIII. stated that 50,000 plough lands had been laid down in grass, that each of them previously maintained an average of 13½ persons, so that 675,000 persons had been deprived of their former means of subsistence.

Thus an immense social change took place in England during the Tudor reigns, which is in many ways more important than the great religious movement with which this period is usually associated. The commercial idea of private property in land supplanted the feudal idea of joint ownership; farming was conducted for a profit instead of merely for self-support; and rack rents superseded customary rents. These changes were immensely aided by the increased facilities for the alienation of land, which were introduced by the ingenuity of the lawyers, and maintained by the action of the Court of Chancery. But the greatest change of all was effected in the position of the agricultural labourers. Pasture required far fewer hands than the raising of crops, and thus a vast number of men were thrown out of employ. At the same time, the eviction of small tenants and the destruction of villages deprived large numbers of the peasants of their hold upon the land, forced them to join the ranks of the hired labourers, and enormously increased the number of men dependent for a livelihood upon wages alone. And the evil was aggravated by the fact that the greatest of all checks on the growth of population, that of small properties or small holdings, was removed in the greater part of England. In no other European country did this occur to anything like the same extent. In France, in Italy, in Germany, as in Russia in our own day, the serfs gradually obtained their freedom, but retained their connection with the soil. They became either peasant proprietors or peasant tenants paying

metayer rents. In England, on the other hand, agriculture was from this time conducted on a system of large farms worked by hired labourers, who had no direct interest in the soil which they cultivated.

The importance of this agrarian revolution cannot be over-estimated. It is the one great and efficient cause of the transformation of mediæval into modern England, of an agricultural into an industrial and trading community, tending more and more to herd together in the great towns. The immediate result was the creation of a large, discontented population without any visible means of subsistence. These "sturdy vagrants" are alluded to over and over again in the Tudor statutes, and their desire to obtain relief by any means is the secret of most of the rebellions of the time, especially of the Pilgrimage of Grace and of the Norfolk rising under Edward VI. The danger which threatened social order was one of the reasons which made the propertied classes cling to and support the crown. The problem of providing work and food for a population which was, apparently, in excess of the resources of the country, was sufficient to tax to the utmost the statesmanship of a period which was not deficient in resolute and capable politicians. It was this social problem—the most serious in our history—which led to the great labour statute of 1563, usually, but incorrectly, known as the Statute of Apprenticeship, and to the series of relief measures which culminated in the Poor Law of 1601.

But legislation by itself would have been insufficient to cope with the difficulty, if it had not been reinforced from other sides. It was fortunate for England that contemporary conditions offered openings for native energy at the very moment when there was an overwhelming impulse to take advantage of these openings. The Netherlands had long been the great home of manufacturing industry, and, though their monopoly had been already infringed, they still retained an apparently secure pre-eminence. But the Netherlands were ruined by Spanish intolerance and by the preposterous taxation introduced by the Duke of Alva. The revolt which was provoked by persecution and misrule kindled a long and destructive war, which was fatal to industry. Flemish artisans hastened in thousands to transfer their acquired skill to countries where they could practise their religion and their crafts in peace and security. England was not slow to welcome the refugees, and to establish within her own

borders the industries which had brought wealth and prosperity to Bruges, and Ghent, and Ypres.

Still more notable was the stimulus given to commercial and maritime development. The mediæval trade routes are well known. The wealth of the East was brought by caravans to the shores of the Levant, thence it was carried by Italian traders to Venice and Genoa, and from those cities it was dispersed along the great roads of Southern Europe. At the same time the trade of the Baltic countries was entirely in the hands of the Hanseatic League. The meeting-point of north and south was in the great city of Bruges, which, at the end of the fifteenth century, was supplanted by Antwerp. The first great check to the traditional course of trade was given by the Turkish conquests in the Levant, which were completed by the occupation of Egypt. The old routes between Asia and Europe were now practically closed, and it was necessary to find a new means of communication with the East.

The attempt to solve this problem led to the almost simultaneous discovery of America and of the route to India by the Cape. From this time the Mediterranean and the Baltic began to lose the importance which they had so long enjoyed. The wealth and power of the Italian republics and the Hanse towns passed to the States with a sea-board on the Atlantic. The first to profit by the change were Spain and Portugal, the pioneers in geographical discovery. At first they aspired to divide the New World between them by the Treaty of Tordesillas, and in 1580 their rivalry seemed to be closed by the union of the two kingdoms under one crown. But the ascendancy of the southern peninsula was destroyed by the resolute resistance of the English and Dutch. The reign of Elizabeth is the heroic age of English seamanship. The exploits of Drake, Frobisher, the Hawkinses, and others, who founded the maritime greatness of their country, have been graphically described in one of the last, and certainly one of the most delightful, volumes of Mr. Froude. The monopoly of the trade with the East, which had been enjoyed for a century by Portugal, was broken through, and the close of the century witnessed the foundation of the East India Company, which was destined to play so large a part in the expansion of England. At the same time the long war in the Netherlands, and the insecurity caused by frequent sieges and military outrages, drove trade from Antwerp to find a new home in London and Amsterdam. When

the war was ended, the revival of Antwerp was prevented by the jealousy of its successful rivals, who secured for a century and a half the complete closing of the Scheldt.

The pressure of population, combined with religious differences, also impelled the English to seek a new career in colonial settlements. In the course of the seventeenth century twelve of the original colonies in North America were securely founded. The motive which had first led the Spaniards to conquests in the western continent had been the desire for gold, and the same motive inspired the expedition of Raleigh, which led to the first settlement in Virginia. But it was probably fortunate, though at first disappointing, for England that her colonies were founded in districts where wealth was produced by agriculture rather than from mining. The prosperity of British North America proved in the end more secure and permanent than that which was given by the more brilliant and attractive products of Mexico and Peru.

Thus England, under the Stuarts, was finally embarked on a triple career for which her mediæval history seemed to have furnished no sufficient training, and which she had only adopted under the pressure of urgent and unforeseen necessities. Spain and Portugal—severed again after 1640—were now decadent states, but England had formidable rivals in France and Holland, each of whom was a match for England in wealth, in naval power, and in colonial possessions. To meet this rivalry, England resorted to the protective measures which were suggested by the mercantile system. The most important of these was the Navigation Act, originally issued under the Commonwealth in 1651, and renewed after the Restoration. By this statute it was attempted to strike a blow at the immense carrying trade enjoyed by the Dutch, and to regulate colonial production and commerce in the interests of the mother country. In many ways the measure was short-sighted and harmful, but it has been claimed for it by Adam Smith that it stimulated the growth of a mercantile marine which proved the basis of the naval power of England.

It was in the eighteenth century, however, that England outdistanced her rivals, and attained that pre-eminence in manufactures, commerce, and colonisation, which has given her a unique position among the great states of Europe. Time allows only a brief estimate of some of the causes which led to the rapid

development of the nation's resources and power in the age of Walpole and the two Pitts. Among the most prominent must be placed the Union with Scotland, one of the greatest achievements of the Whig party. It has become a commonplace to enumerate the benefits, and especially the material benefits, which the Union conferred upon Scotland; and it is only fair to say something of the advantage which that measure brought to England. It is not only that Scotland, once admitted to full partnership, devoted rare energy, zeal, and ability to further the interests of the new firm, and that Scotchmen played a prominent part in the development of industry and trade, as well as in the improvement, extension, and government of the colonies and dependencies. These services, great as they have been, were not absolutely indispensable; at any rate, considering the incessant grumbling that Scotchmen were always to be found getting the best posts and the most advantageous openings, it would be harsh to assume that others could not have been found to fill their places. The essential service rendered by the Union was more subtle and less definite in its character. If Scotland had remained a separate and jealous state in the eighteenth century, if it had continued to provoke foreign complications by new Darien Expeditions, if it had ever been on the look-out to make embarrassing arrangements for the succession or for occasional regencies, there can be little doubt that it would have been a serious obstacle to the progress of England, and that it might have helped its old ally, France, to escape from many of its worst difficulties: and, from this point of view, it is important to remember that these advantages were not gained by the mere paper Act of Union, but rather by those circumstances and those administrative measures which led to the subsidence of the bitter discontent which the Union at first provoked. As long as Scotchmen remained dissatisfied and ready to welcome rebellion as a means of recovering independence, the usefulness of the Union to England must have appeared more than doubtful.

A formidable antagonist to England was removed early in the eighteenth century by the decline of Holland, which furnishes one of the most curious problems of history. It was not the result of military failure or defeat, for it was coincident with the close of the War of the Spanish Succession, in which Holland had been one of the three great states in the victorious Grand Alliance. In the treaty of Utrecht the Dutch had obtained most favourable

terms in the cession of the Netherlands to Austria, in the erection of the "barrier" against French aggression, and in the stipulations for the continued closing of the Scheldt. Nor was the decline the result of commercial or financial disaster. Whenever Adam Smith, writing some sixty years later, wishes to give an illustration of a country with great accumulated wealth, he alludes to Holland: according to him the Dutch, in spite of the Navigation Act, still possessed the largest share of the world's carrying trade. Yet in spite of Dutch victories, and in spite of Dutch wealth, there can be no doubt that Holland drops out of the list of great states after 1713, that she ceases to be a rival of England as she had been in the days of Tromp and De Ruyter. And the decline is not merely military or political; it extends to the literary, intellectual, and artistic activity which had characterised the Republic in the days of its greatness. It would be superfluous here to discuss the causes of this decline, and to examine how far it was due to exhaustion and excessive taxation, and how far to the weakness of a federal government, and to the relaxation of moral fibre when the pressure of the long struggle for self-preservation was removed, which had for a time silenced domestic discord, and had called forth heroic qualities proportioned to the magnitude of the interests at stake.

The disappearance of Holland from among the great powers left Britain face to face with France. The great struggle between these states in the eighteenth century has been called by Professor Seeley the second Hundred Years' War, in which the prize contended for was maritime supremacy and expansion in America and Asia. The victory of the island power in this prolonged contest must be regarded as one of the greatest causes of British ascendancy. The triumph has often been attributed to the superior qualities of the British as colonists, but it may be doubted whether this explanation is correct, and it is certainly not exhaustive. I should be inclined to lay greater stress on the fact that Britain had a far stronger initial impulse towards expansion than France, with its population of peasant proprietors and metayer tenants. England had also a sounder system of finance. The Commonwealth had abolished the mediæval methods of taxation, and had substituted a system which, whatever its defects in detail, had the supreme merit of making the revenue proportionate to the national wealth. In France, on the other hand, financial reform was successfully resisted by the privileged classes, and the

old exactions, oppressive and unfair in their incidence, were retained till the Revolution. Hence it was that France reeled under the burden of a military expenditure which Britain was able to bear with comparative ease. Above all, the attention of England was in the main concentrated upon the naval and colonial struggle, whereas France throughout the century was engaged in a series of great continental struggles—wars with Austria, wars with Prussia, wars to defend the Republic, and wars to aggrandise the Empire. These wars diverted the attention of France from her interests in India and America, and enabled Britain to gain and to keep, except for a short period during the American revolt, that naval ascendancy which, as Captain Mahan has so brilliantly shown, was the real efficient cause of her ultimate triumph.

Two other circumstances deserve mention as contributing to the unique success of Britain in manufactures and commerce. The one was the enormous stimulus given to industry by the great mechanical inventions associated with the names of Hargreaves, Crompton, Arkwright, and Watt. The other was the notable change in economic theory which began in the latter part of the eighteenth century. It was a most fortunate event that this country not only produced an Adam Smith, but also took the lead in translating his precepts into practice. His teaching dealt a fatal blow to the so-called mercantile system, with its short-sighted conception of the benefits to be derived from international trade, and with its disastrous methods of colonial policy. His lessons on the latter point were powerfully brought home to statesmen by the great American revolt, and it was by no fortuitous coincidence that the "Wealth of Nations" was published to the world in the same year as the Declaration of American Independence. The carrying into practical effect of the teaching of Adam Smith, first by Pitt, and then, in later generations, by Huskisson, Peel, and Gladstone, contributed the most powerful stimulus to the modern advance of trade and of the industrial production which supplies material for trade.

It is not for me on this occasion to trace the economic history of the country to the present day, or to discuss whether we are likely to retain that eminence in manufactures, trade, and colonisation which we were driven by circumstances to seek, and which we have clung to ever since. I will only suggest one obvious method by which we might regain some of that start which, in

some respects, we have been losing of late. We were the first to introduce many of the chief methods of production and locomotion; we were the first to formulate and to practice the true principles of trade; it would be well for us if we could also be the first to solve the problem set before us in the rival interests of employers and employed; if we could provide some method of averting those desperate struggles which waste the best energies of both classes, and assuredly contribute nothing to the material welfare and progress of the community.

VI.—*Women's Industries in Scotland.* By Miss MARGARET H. IRWIN, Assistant Commissioner, late Royal Commission on Labour.

[Read before the Society, 18th March, 1896.]

IN the paper which I have to read to you to-night I shall try to confine myself to such features and characteristics of women's industries as present themselves, not to the partisan of either capital or labour, but to the economic investigator. The facts that I shall have to present to you were chiefly collected for the Royal Commission on Labour, and were collected, if I may be allowed to say so, with the strictest impartiality from both employers and employed. The wages figures and other statistics on which I have based my conclusions were supplied to me from the books of the employers (and in the case of the Glasgow Cotton Trade, twenty firms were visited), and, when possible, the books and billets of the workers were also examined.

I may say, to begin with, that I shall try to avoid, as far as I can, the raising of controversial points, or of giving merely speculative personal opinion. I shall also avoid opening up such large questions as the comparative merits of the collectivist and the individualist systems. All I have to say relates to the commercial system as it is—not as, in the opinion of some persons it ought to be, or it might be. I only propose to put before you, then, some of the features that characterise women's industries in Scotland at the present time, leaving to others to point the moral, but believing, at least, that the first step towards any solution of a problem is to become acquainted with the conditions that constitute it.

The point in connection with women's trades in Scotland for which I wish more particularly to ask your consideration is the decay of some of the major industries employing women, the causes which (it is generally alleged) are bringing this about, and how far the same may be remediable. The subject was very much before me during my investigation in Scotland for the Royal Commission on Labour, and has been before me in one form or another ever since. The decay of these industries is a question in

which both employers and workers must have a common interest, and the remedies are points on which, in some cases at least, I hope they may find some common agreement.

The substance of what I have to say I have already said on several occasions before representative bodies of workers, but this is the first time I have had the honour to place these points before an assembly in which, presumably, the interests of capital are chiefly represented.

I think no one who has the opportunity of taking a bird's-eye view of women's industries here, or who has occasion to inquire into their past as well as their present conditions, can fail to be struck by the seriousness of the outlook in many of them, and how, in certain trades, in spite of an occasional uplook, there seems to be a steady downward tendency all along the line. Wages were reported to me to be falling steadily, until, in some cases, they had reached a bare subsistence level, and what made the hopelessness of it all, and the pitifulness of the workers' struggles against ever-increasing reductions in wages, was that the industries themselves were leaving the district and leaving the country, and few of those most concerned seemed to know why they were going, or where. It was noteworthy that many of these trades were not "fashion" trades, but those producing commodities that were used daily and in large quantities by the public generally.

It is not possible, of course, for me to do more than touch on a few of these trades. There were certain minor industries that were said to be suffering from the operation of vexatious tariffs, from the competition of foreign prison labour, and the irregular competition of partially-supported labour in industrial institutions at home, all of which form an interesting study to the economic investigator. But those which I wish more particularly to speak of are the textile trades, because of their greater local interest and importance, and also because it seems reasonable to think that the causes operating against the prosperity of these are to some extent remediable. One may classify broadly the industries which employ women as—

(*a*) The Textile Trades.
(*b*) The Clothing Trades.
(*c*) Miscellaneous Trades.

There is, perhaps, no centre in the United Kingdom that affords

so rich a field for the economic investigator as Glasgow does. It is estimated that there are over 300 different industries carried on here, which is a larger variety than is to be found even in London itself. We have nearly all the major industries represented on a scale sufficiently large to enable one to study the general features and conditions of these industries, while, owing to their not being spread over too great an area, they are not so affected by varying local conditions in different districts as to be broken up into small sections, practically forming separate trades. In this they may be compared with the clothing trades in London, for example, where, I am informed, the conditions of the tailoring and other trades are so different in the East and the West Ends as to render them to all intents and purposes different trades in their respective districts.

The textile trades in Scotland comprise, as every one knows, the cotton trade (now almost exclusively the weaving branch of it) in the western district, the jute and linen trades of the northern district, and the tweed and woollen trades of the southern district. Of course, there are numerous other branches, such as thread, carpets, a little silk, and other things; but while these are really of considerable extent and importance, they may be regarded as forming, relatively, the minor textiles.

The great feature which differentiates the textile industries of Scotland from those of England is that, while in the latter country they are followed by both sexes, in this they are practically *women's* industries. Strange to say, this fact does not seem to be generally understood by those outside of the trade itself, and I have even found that those whose business it was to look into these things were not only unaware of the fact, but extremely slow to realise it. And yet the absence of male labour in the main departments of the textile trades in Scotland—that is to say, the spinning and weaving—seems, so far as the evidence submitted to me went, *the* fact that had, perhaps, exerted the most important results on the development of the textile trades here, and the economic position of the workers employed in them.

The only exceptions to the employment of women as spinners and weavers worth noting are—the spinning of woollen yarns in the southern district, which employs men and lads; and carpet-weaving, where some of the heavy hand-looms still linger, and are worked by men. But a rooted prejudice exists among the working classes of Scotland against the employment of men on the power-

looms. A manager of a large factory told me that he had once made an effort to introduce male labour into his weaving department, and that, after a few weeks' trial, the men gave it up, being unable to stand the ridicule to which they were daily exposed for taking up "women's work." One obvious reason for the textile industries being abandoned to women in the northern and western districts is that the men are attracted by the highly-skilled and highly-paid mineral, metal, and building trades.

It is estimated that about two-thirds of the textile industries of Scotland are carried on in the western district, the goods manufactured being chiefly cottons, including ginghams, muslins, zephyrs, and shirtings—all requiring a high standard of skill in their production, and much care and attention in weaving.

It is a generally-accepted fact that the cotton-weaving of the West of Scotland has been seriously damaged in the past by the competition of Lancashire, and that the outlook for the future is overshadowed by the same cause. The bulk of the plain calico-weaving trade has practically gone, and it is only in the finer goods, already enumerated, and popularly known as "fancies," that Glasgow has been able to hold her own as yet.

In the case of fine goods the "runs" are short, and the profit, although relatively high when compared with the long "runs" of plain goods, is not so high absolutely as to induce the Lancashire manufacturers to employ their machinery in the production of short "runs" of fine goods rather than in long "runs" of plain goods. Thus, while Lancashire has undoubtedly secured the bulk of the cotton-weaving trade, it has taken especially that section of the trade which is profitable on the large scale, and has, so far, left alone that section which is profitable on the small scale.

And now let me note a few of the reasons which were offered as explaining why Lancashire has out-distanced Glasgow in the race. It is generally believed in Glasgow that the proportion of men weavers in the English factories is an immense advantage for the English manufacturers. The men's continuity at their work, their greater physical strength, their ability to keep the machinery in order from day to day by means of repairs, all combine, it is asserted, to give a higher standard of application and production (especially quantitative production) in Lancashire than in Scotland, where the trade suffers from the general causes and interruptions which affect women as workers.

Heredity is also considered to enter into the question. In Lancashire the one business of life from generation to generation has been the textile industry, and possibly the high degree of deftness, due to the concentration of energy, appears in the young generation as natural aptitude, and the work produced involves less physical strain on the worker. Again, it is a common arrangement in the English factories for a man, his wife, and all their family to engage a group of looms and work to each other's hands, and a working woman in Lancashire frequently returns to the factory immediately after marriage, and works by her husband's side. In Scotland, on the other hand, weaving is only one of many occupations, and is confined to the sex whose working life is most subject to interruptions, and it is not so usual in Scotland for a woman to return to the factory after marriage unless necessity drives her. Lastly, the opinion of both manufacturers and operatives, so far as I have collected it, is that the importance of the textile industry in Lancashire, as being practically the one great outlet for commercial energy, has an effect on the enterprise of the English manufacturer, and obliges him to keep abreast of the times in the matter of machinery and appliances. And here we come to a point, the importance of which it is, I think, impossible to over-estimate: I mean the difference in the loom system employed in the two countries.

In Glasgow women never attempt more than two looms for coloured goods, and very seldom more even for plain calico. It is affirmed by Glasgow manufacturers that in England, on the other hand, where men and women work together, and are paid at the same rate, a spirit of emulation, not to speak of the pressure of competition for employment, induces the women to take three and four looms like the men, a practice which the system of farming-out the looms among members of the same family lends itself to. Working women in Scotland are very tenacious of their habits, and they are sometimes said to be a little lacking in adaptability to new circumstances and methods. But, however this may be, there is no point on which the Glasgow weaver is more fiercely combative than this of the two-loom *versus* the three-loom system, and none on which it is more difficult to convince her that any system but her own is practicable.

To illustrate how strong the feeling is on this point, I may give the following instance:—Some five or six years ago a Glasgow manufacturer of plain calico in the Kelvinhaugh district, feeling

the hardship of a decaying industry, and the inconvenience of being obliged to send large orders to Lancashire every year, owing to the comparative cheapness of production there, endeavoured to introduce the three-loom system into his Glasgow factory. The girls immediately struck work. After the strike had gone on for some days, the Glasgow Trades' Council and the Council of the Women's Protective and Provident League took the matter up and entered into negotiations with the employers. The latter offered, very fairly, to provide new machinery, to introduce the change gradually, and to pay the wages due to increased production. The Trades' Council and the Council of the League endeavoured to persuade the girls of the desirability of the arrangement, pointing out to them that it would result, not only in larger wages to themselves, but would help in the very important matter of keeping an industry in this district. The workers remained unconvinced, and finally the League and the Trades' Council offered to send an expert to Lancashire to investigate the difference in the system there. This was done, and the report brought back was to the effect that the Lancashire women were working three and four looms of the same kind and on the same fabrics as in Scotland. The workers, however, refused to allow the experiment to be tried, and the proposal had to be abandoned.

This case was a comparatively simple one, as the work done, both in the Scotch and the English factories, was of the same kind, and it is a matter to be greatly regretted that the representations of both the Trades' Council and the Women's League should have failed to bring about the desired arrangement.

Where it is more difficult to see one's way to advise the workers is in cases where an attempt is made to introduce the Lancashire loom system, and at the same time to retain the Glasgow fabrics and Glasgow standard of quality. And it is here, it seems to me, that considerable confusion has arisen in the minds of the public; and it may be stated, once for all, that no comparison between Lancashire and Glasgow trade is possible, because each is engaged in quite a different class of work from the other.

There has never been any question of the superiority of the Scotch weaver in the production of coloured cottons, popularly known as "fancies;" and in so far as *quality* is concerned Glasgow holds her own in the market, and constitutes, as one manufacturer said to me, "a big pattern-shop in coloured cottons for the rest of the world." And after very careful inquiries I am

satisfied that it would be physically impossible for the weaver to undertake more than two looms in the weaving of "fancy" cloth, requiring the same care, attention, and skill in its production that the customary Glasgow standard demands.

Further proof of the difference of skill was furnished a few years ago, when, during a dispute which occurred between a Glasgow firm and their workers over a reduction in wages, the cloths were cut out of the looms and sent to Lancashire to be woven. The employer there to whom it was taken declared that it needed so much more time and care than their usual work that his weavers would lose about 25 per cent. on their wages during the week that they ran it, and that they "were glad when they could get it off their looms."

But the difficulty that now threatens our local cotton trade is that Lancashire is producing cheap imitations of the Glasgow goods, which are taking the market. And some little time ago I was shown samples of Lancashire cloth that had deprived a Glasgow firm of a contract, and which at a little distance looked equally attractive, although a closer inspection showed, to a woman's eye at least, a great inferiority in the fabric. But, unfortunately, a large proportion of "fancy" cottons are used for purposes for which fineness of quality is not a *sine qua non*, and the inferior, but cheaper, fabric is likely to be preferred.

It was owing to the successful competition of the cheap imitations of Lancashire in the line of "fancy" cottons that more recently a firm in the northern district of Glasgow locked out their workers until they should consent to try, not three "fancy" looms, but one "fancy" and two comparatively "plain." By the advice of the Women's League, of which the majority of the girls were members, a number of them were induced to give the system a trial, but a large proportion refused to do so.

I trust you will pardon me if I have dwelt with undue length on this point, but it is one round which so many difficulties cluster, and on the solution of which the development of our leading textile industry—nay, possibly even the question whether or not we may be able to retain it at all—largely depends. It is also a point regarding which considerable misapprehension seems to have arisen as to what was the real attitude towards it taken up by local societies representing the interests of the women workers, and I am glad to have this opportunity of explaining what has been their policy and their action in the matter.

One point on which personally I feel very strongly is, that the responsibility of settling so important a matter as this should not be left to any single firm or their workers. If a complete change in the system of weaving is necessary, it seems desirable that the question should be fully considered and discussed in all its bearings by representatives of all the interests concerned and selected from over the whole industry—say, by such a body as the Chamber of Commerce on the one hand, and by the workers' organisations on the other; or a joint conference of manufacturers and operatives might take the matter up. Perhaps an adjustment might be made by the workers on their side agreeing to give the Lancashire loom system a fair trial, and by the manufacturers on their side agreeing to adopt a fabric which would make this possible.

Whether it is desirable or not that Glasgow should lower her standard of quality in order to increase her quantitative output, or whether it would be an unmixed good that male labour should be introduced into the spinning and weaving branches of the Scotch textile trades, are matters on which there may be much diversity of opinion; but the evidence of employers or workers seems at least to point to the fact that Glasgow cannot "eat her cake and have it too," and an adjustment of some kind must be arranged, unless we adopt the view that I have heard some English manufacturers put forward—namely, that we have no right to spinning and weaving, these ought to go to the districts where nothing else has been done for generations, and that Glasgow should keep to her iron and building trades. But then the question arises, What are we to do with our women workers? And meantime we are face to face with the fact that there are at present 25,000 fewer power-looms employed in the leading textile trade in Glasgow now than there were twenty years ago, and to realise the full significance of this we must take into account the growth of population and everything else in that time.

To sum up, then, plain calico-weaving has practically gone, and fancy cotton-weaving is seriously threatened. When we look to the other main branch of the cotton trade, spinning, we find that there are now only two cotton-spinning mills in Glasgow, and two weaving factories that have a cotton-spinning department. This used to be an important industry, but ten or twelve mills were burnt down in Glasgow during late years and have not been rebuilt. The reason given by several employers and operatives

for this falling-off in the cotton-spinning industry was that the owners of these mills had made large fortunes, and the next generation were lacking both in commercial enterprise and the stimulus of need to rebuild them.

In both mills the same story was repeated to me, namely, that "spinning is on the decrease in Scotland," the same causes being said to operate here as in the weaving trade—the competition of Lancashire, and also the variety of industries drawing away both capital and labour, and thus preventing spinning from attaining the position of a major industry.

On the other hand, it was alleged that Scotch firms have slightly the advantage in the meantime, from the fact that spinning with them is the product of women's labour, which is both cheap and unorganised, while in England it is the product of highly-organised and protected labour.

I can only note briefly some of the points in the other textile centres in Scotland. To take the jute trade of Dundee first: two features may be noted in regard to it:—1st. The employment of children's labour, which, however, is decreasing every year, owing to the increasing restrictions of educational tests; 2nd, the large proportion of married women employed in the mills.

The second point is probably a corollary of the first, and I was informed by the School Board Officers in Dundee that large numbers of widows and married women with improvident husbands flock to Dundee to find employment for their children under the Half-time System. Also, the preparing departments of the jute industry afford employment for the unskilled and casual worker, thereby attracting married women in necessitous circumstances. In one mill, a large and representative one, the firm kindly supplied me with an analysis of the condition of their workers under this head, which showed that in the preparing departments 97 per cent. of the workers were married women, while in the spinning and weaving departments, where a much higher degree of skill and continuity was required, the percentage sank to 19 and 14 respectively.

But over all the large percentage of married women employed in the textile trade in the north was very marked compared with that in the west, where, in cases in which statistics could be got, it was as low as 5 per cent.

What Lancashire competition has been to the cotton trade of the west, Indian competition has been to the jute trade of the

north, only more so, and experts are agreed that, in spite of occasional uplooks in the home trade, the competition of Calcutta is a permanent and growing danger for the future, and demands the gravest attention from all interested in the jute trade in this country. For here, unhappily, the cause lies too deep to be got at by any mere adjustment of a loom system, or change of the quality of a fabric. It is unnecessary for me to point out the factors of cost of labour reduced to a minimum through cheap cost of living, the advantage of having the raw material at the door of the mill, and other things, that have helped Calcutta. And, to start with, the industry had always a somewhat precarious footing here, jute being a secondary fabric and only employed in many departments when cotton is too dear.

As to cost of living for natives in India, as has been aptly said, theirs is a "rice civilisation." I take the following figures from a series of valuable articles on the Indian jute trade contributed to the *Dundee Advertiser* by Sir John Leng, M.P. A Bengalee family, consisting of husband, wife, a boy, and two girls, may earn amongst them 9s. 6½d. a week. The expenses of the same family, including food, clothing, and rent, amount to 5s. 5d. a week. This wage thus gives them all they want, and allows them to save 4s. 1¼d. a week besides. And when we also take into consideration the fact that the supply of labour in India is practically unlimited (in Bengal alone there is a population of over 70,000,000), we realise the nature of some factors in the problem that stares our home jute trade in the face. At the same time, it must, of course, be remembered, that the saving in the cost of labour is not quite so great on the side of India as might at first sight appear. Cheap labour is nearly always inferior labour, and this case is no exception to most others. It takes a larger number of natives, with their inferior physique, to accomplish the same amount of work that Europeans get through. Also, the cost of labour is very heavy in the supervision departments of the Indian mills, the work there being done by Europeans. For while cost of living in India is low to the native, it is exceedingly high to the foreign white man. But, even after giving due weight to these and other counter-considerations, it seems to be generally felt that a balance of *natural* advantages remains on the side of India. What makes the case so hard for Dundee is that its hopes are mostly, like Antonio's, "all in one bottom trusted." And while there may be a modicum of advantage in the fact that the development of the industry in India opens up

opportunities of employment for young men of the middle classes in the commercial and the supervision departments of it, and so supplies a want that has been badly felt in many places, and notably in Dundee, an encroachment by Calcutta on the jute trade would mean a great and permanent loss to the industrial classes here, and also to the smaller capitalists, who cannot afford to build mills in Calcutta to take the place of those at home; and it is probable that much hardship and suffering will be felt before the play is played out in Dundee. For my part, I am inclined to think that if it is satisfactorily proved that an industry can no longer provide a comfort wage for those engaged in it, and there is conclusive evidence that it will not do so, it is better it should go, and the main point to be studied is to secure, if possible, that it shall go gradually, so as to give both capital and labour time to seek out new channels. The head of one of the largest firms said to me lately, "We have come to see that our jute trade must go; all we ask is that the pressure of competition might be abated a little, so as to give us time to turn round." But this is pre-eminently a case in which conclusive evidence must be had, and nothing left to speculative opinion.

One feels how great a benefactor to any community whose industries are seriously threatened would be the man who could introduce a new textile that would so far employ the plant and the labour of the old.

One small point which is noted with satisfaction is that the menace of a common danger has brought together the representatives of capital and labour in Dundee, and the Trades' Council and the Chamber of Commerce there recently joined hands in an appeal to Government to inquire into the conditions under which the jute industry is carried on in India by British subjects, and how far these might, as was alleged, exceed the limits of fair competition with their fellow-subjects at home. On the basis of preserving the trade for Dundee, naturally perhaps, such an appeal would not meet with much support outside of Dundee itself; but a perfectly legitimate ground for it would be to ascertain, in the view of a growing industry in the east, whether the same was being prosecuted under fair and healthy conditions. Obviously, care would have to be taken not to seek to impose such factory legislation as is in force here, but only such as would be compatible with the enormous difference in local conditions. And that could only be undertaken after carefully ascertaining what the local

conditions really are—a point on which there is much conflicting evidence.

But, at least, we can welcome the fact of these two bodies working together for the common good, and also more recently taking up conjointly the subject of conciliation boards. And, again, one asks could they not be employed here, and in other parts of the country, in investigating how far the falling-off of certain industries is due to irremediable causes, and in cases where they *are* irremediable, to consider the introduction of others in the common interests of capital and labour, and to avoid the useless struggles involved in strikes and lock-outs.

Whether or not it be true, then, as some say, that our cotton-weaving *must* go to Lancashire and our jute to Calcutta, because these places have facilities that we can never attain to, at least let us have full and definite information as to the forces with which we have to compete, and not expend our strength in a struggle that can best be compared to trying to sweep back the Atlantic with a broom. Let employers and workers take counsel together, and try to discover what they *can* best work at, and see that every opportunity is given for starting new industries to take the place of those which we are losing. And let us avoid, above all things, leaving such questions to be settled, as opportunity arises, by isolated firms or bands of workers.

The only other branch of the textile industry which my time allows me to say a word on is linen-weaving, of which Dunfermline is the headquarters. The trade is a highly-skilled one, and the weavers' wages may, in many cases, average about 20s. a week. An interesting and important experiment was tried by a firm there by the introduction of a nine-hour day. The initiative was taken by the employers, who called the piece-workers together and put the proposal before them. A vote was taken, which was practically unanimous in favour of the reduction of hours. The experiment lasted for four months, and was changed to nine-and-a-half hours mainly to allow of a more equal morning and afternoon shift. The employer told me that he got a larger production for the nine-and-a-half than for either the nine or ten hours' day, while the result to the workers was that those on piece-work (all over) made 2½ per cent. more money. A few of the very best workers, who were working at full pressure before, lost, however, about 1s. a week. I found that the reduction in the working hours, even when accompanied, as in a few cases, by a slight reduction in wages,

was regarded as an immense benefit by the workers. Some of them assured me that the reason why their wages were increased was because they "put their mind into their work now."

The firm in question is engaged in the manufacture of fine household linen, requiring considerable skill in weaving; and in considering the results to production from the shortening of the working day, it may be remarked that one of the most important elements in this industry is the physical condition of the worker and her ability to give the care and attention necessary to the production of good work. In this it may be compared with other branches of the textile industry, such as spinning and plain calico-weaving, where the chief factor is the machinery, and the production is more largely dependent on, and limited by, the time the machines are allowed to run.

Better railway facilities for getting into this centre would be a great boon to the workers. There is a steady demand for female labour at a good remuneration, and, owing to the absence of employment for men, Dunfermline cannot meet the demand sufficiently. In consequence, large numbers of women come from the surrounding districts, and many of them have to walk three or four miles to their work.

This same absence of employment for men in some parts of Ayrshire, due to the falling-off of the mining industry, is having, I was assured, a notable effect on the textile factories there. It is not possible to get a sufficient supply of female labour to develop the industry, while the wages are not high enough to tempt women to leave their families and come and settle as independent wage-earners.

I cannot state too emphatically my belief that the wages question is the question of paramount importance for the social reformer. I regard it as the sphinx that will continue to bar all progress and healthy development until we have in some degree solved its problem; and whether my hearers may be able to agree with me or not, I am obliged to say I think we must obtain a certain sound *material* basis for every human being before anything can be done for his mental or moral elevation. We hear sometimes of a "wage that just keeps body and soul together." To my thinking that usually means the wage best calculated to keep them apart; for if the whole physical power is engaged in a hand-to-hand fight with poverty, I am afraid very little energy can be left for keeping life in the mind or soul. Speaking

generally, I have always found that the conduct, health, and standard of social and family life among working women is more largely regulated by the *wages* they receive than by anything else. This rule is, of course, subject to modification in individuals, through temperament, training, and other circumstances; but I have no hesitation in stating, as a general principle, that where women's wages are high the standard of conduct, health, and family and social life will usually be found to be correspondingly high. When wages are low the reverse is the case. Becky Sharp thought it "easy to be good and amiable on £10,000 a-year," and the average working girl usually finds it much easier to be good and amiable on 20s. a week than on 5s.

The two most salient points in women's wages are (1) the difference between the wages paid to men and those paid to women for work of the same nature and efficiency; and (2) the absence of a standard or uniform rate of payment for the same work among women themselves. The textile trades in Scotland, being followed by women exclusively, afford, of course, no illustration of the first point, but they offer a striking example of the second. And it is a point worth considering, as this absence of a declared and uniform rate of wages for the same work throughout the trades has apparently been the chief source of difficulties between employers and workers in the weaving trades in Glasgow. Each factory starts on a basis relative only to its own work, and rates accordingly; and although it is sometimes asserted that the result is a uniform, or almost uniform, rate of wages throughout the trade, the facts do not bear this out.

For example, five firms who supplied me with the wages figures from their books were found to be paying rates varying from about five to fifteen per cent. for the same fabric. The variation in a market so small as the one in question is very remarkable. It is difficult to explain it otherwise than by ascribing it to the more or less arbitrary fixation of price by the employer, and the absence of adequate means on the part of the worker to control this.

The workers complain that there is no guarantee that any firm may not reduce wages rates as it pleases, without their being able to compare those which they receive with those current elsewhere. I find there is a general under-current of discontent among the women workers regarding this system of arbitrary fixation, as they feel it offers a temptation to reduce wages to the zealous manager anxious to give a good account of his stewardship,

and to the less scrupulous employer who "cuts" prices and recoups himself at the workers' expense. Workers having had in the past no organisation strong enough to combat this evil, and no centre, such as an organisation affords, for accurate information as to current rates have, in most cases, been obliged to submit. On the other hand, many employers also feel very strongly both the injustice to their workers and the danger to themselves in this system, and I have again and again been told by those who wish to give a just wage how they are handicapped by this, and how advantage is taken of it by less scrupulous competitors. Some years ago a society was formed under the name of "The Power-loom Cloth Manufacturers' Association of Glasgow and the West of Scotland," of which one of the objects was to establish a more uniform rate of wages and prices, and so to regulate competition in the interest both of employers and workers. It is much to be regretted, however, that the attempt fell through. What is known as the "particulars clause" in the Factory Acts aims at providing a certain amount of protection for the workers on this point, but, unfortunately, like many other provisions of the Acts, it operates least effectually in those sections of the trade where it is most needed.

When we turn to the clothing and miscellaneous trades, we find the two points that I have mentioned, and which may be regarded as the family features of women's industries generally, very amply illustrated. To take the tailoring trade, for example, where men and women compete more closely with each other than they do in perhaps any other. It is estimated that in Glasgow alone over 5,000 women are employed in this trade, and in Glasgow there are only three shops where women are paid the same rates as men for doing the same work. In this trade there is a very strong organisation among the men workers. They have drawn up an elaborate and complete wages list, known as the "Tailors' log," in which everything is rated at a fixed price, which price the tailors have been able to obtain owing to their being strongly organised. A further result of organisation among the men is that they have been able to protect the first-class shops against the incursions of what they term "female pirate labour." In the shops of the second and third class, where the workers are less skilled, less intelligent, and consequently less thoroughly organised, the women have forced an entrance, and, while the men are paid strictly according to "log" rates, the women, who work beside

them and on the same jobs, are paid at whatever price the employer decides to offer, and this price varies in every shop. So that in the tailoring, as in most other trades followed by women, the woman's wage is a matter of arbitrary fixation on the part of the individual employer. For instance, when a man tailor makes a dress vest, he may receive 7s. 6d. for it. When a woman makes the same vest, she gets 3s. 6d. For garments for which the man's rate is 3s. 6d., the woman gets 2s. and 1s. 6d., and sometimes as low as 9d. The result of this is that a rapid displacement of male by female labour is going on in shops of the lower class. As in other industries, the accompanying features of this are, besides decreased wages rates, increased use of machinery and extension of the sub-division of labour system.

Let us now turn to the typographical trade.

Here, in many sections of it, the women do exactly the same work as the men, and their respective wages rates are as follow:—On the time, or, as the printers call it, the "stab" wage, a girl may start at 4s. per week and rise to 9s., 12s., and 15s., and in rare cases to 18s. The "stab" wage for men is a minimum of 30s. and a maximum of 37s. 6d. On piece wages the men's rates are 6¾d. per 1,000; the women's from 3d. to 5d. per 1,000.

But, while it is true that in many sections women do work of the same nature and efficiency as the men, it is also true that there are some parts they cannot do, such as lifting the heavy "formes" and "chases," &c., and for which supplementary male labour has to be employed. And this is usually given as the reason for the lower rates paid to women. It was difficult to get evidence as to the exact cost of this supplementary labour. One employer estimated it as adding 1d. per 1,000 to the cost of the women's work, leaving 1¾d. per 1,000 as the real difference in pay between them and the men, while a woman worker, again, told me that in her workshop where twenty girls were employed, one man did all the supplementary work for them and his own work in addition. The evidence on the whole seemed to point to the conclusion that, while there was undoubtedly a difference between the work performed by the respective sexes, the difference in their pay was out of proportion to it.

Then there are factories where there hangs inscribed the following legend:—

"Men's rates for cigarette rolling, 1s. per 1,000,
Women's rates for " " 9d. " " "

Now, it seems reasonable to expect that when there are large discrepancies in the wages of the worker, a corresponding difference would be found in the prices charged to the public for the goods made by the respective sexes. So far as I am aware, however, the difference stops short at the pay-books of the worker, and the vest and the cigarette made by the women has the same value put upon it when it goes into the market as that made by the man. If, however, any gentleman present can inform me of a reduction made in his tailor's or tobacconist's bill because of the goods supplied being the product of women's labour, I shall be glad to note the fact for future reference.

I have on several occasions endeavoured to learn from employers on what principle they paid one rate to a man and another to a woman, in cases where, according to their own statements, the work done by both sexes was the same; and the reply most frequently made to my inquiries was—"Oh! well you know a woman's wage always *is* less than a man's." If I were so unreasonable as to thirst for more enlightenment, and press inquiry further, sometimes a man of more speculative intellect would explain that "it takes so much less, you see, to keep a woman than to keep a man."

That may be so or not—I have heard it questioned;—but our industrial system is founded, theoretically at least, on the principle of payment of the worker not according to his needs, but according to his production; and I fear many of these same employers would have felt both indignant and alarmed had they been told that by this they were advocating an extreme socialistic doctrine, and I do not think many of them would have cared to recommend its general application.

The difference in the nature of the various trades is so great, that one hesitates to put forward any statement as being safe in application to them all, and prefers to consider each trade individually. But leaving a wide margin for exceptions, I would venture to suggest that the lower earnings of women workers may be generally attributed to the traditional standard of a "woman's wage;" the absence among women of the protection that men have in their trade organisations; and, also, speaking generally, the women's inferiority of skill in many industries. This last is, however, in my opinion, not frequently commensurate with the great difference in pay.

Obviously, one of the most serious results arising from the disorganised competition of women is that they are being more and

more made use of to undersell men in industries that are open to both sexes, and to such an extent has this been carried that in some districts in England whole families are now working for the wage formerly earned by one male member.

I know of no sadder spectacle than that of women standing in the market-place with their fathers, and brothers, and husbands, and sons, and striving to snatch from them the scanty morsels of daily bread.

In many trades women have been employed as cheap foreign labour is employed, and have done infinitely more harm than has the needy Teuton or the "Heathen Chinee." Of course, this cuts both ways. By reducing the earnings of the fathers and their husbands, always more and more women are being forced into the labour market, which they enter at a permanently reduced wage, and which, if the wages of their menfolk were what they ought to be, they would, in all probability, not enter at all. And so the struggle grows fiercer and fiercer day by day. Owing to want of agreement among themselves as to what they are to accept as a "fair day's wage for a fair day's work," women are unable to resist the ever-increasing reductions, until, as some political economists tell us, there is no limit but the starvation limit, to which, with time and increased competition, women's wages may not sink.

And here I should like to point out the helplessness of individual employers to keep up wages. No employer can by himself keep up wages, however much he may wish to do so, and he is frequently as much at the mercy of disorganised competition as are the workers themselves. When firms in the same trade are competing with one another, and one takes contracts at a figure much lower than the current one, and reduces his wages in consequence, it is seldom the wages of his own workers only that are reduced. The wages of all the other firms that sell in the same market with him are ultimately reduced also.

And one word here as to the functions of workers' trade associations. In my opinion, these should be something more than mere fighting organisations, or machines for raising wages. Or, to put it another way, in order to do that effectually, they must keep themselves widely informed as to the inherent characteristics of the industries to which they are attached, of the exact nature and extent of the competition in the trade, and, as far as possible, with its history, and its developments, past and potential.

It seems to me that these are points on which all who work in and lead such movements must of necessity acquaint themselves, so as to be able to distinguish between the remediable and irremediable causes of low wages or failing trade, and so as to avoid waste of force in fighting such things as, say, the introduction of labour-saving machinery (which is an accompaniment of either the advance or the decadence of civilisation—according as one's individual point of view has been toned by Mr. Ruskin or not—but, in any case, an accompaniment); also to avoid prolonging the death agony of an industry producing what the public no longer wants, as, for instance, the trade in Paisley shawls (and one regrets that the public no longer wants those beautiful things), or tambour muslins; and, again, to avoid wasting ammunition on such permanent and irreducible factors as the competition of other countries having great natural advantages in the way of cheap labour, resulting from the low cost of living.

To distinguish between these and a decrease in wages, due either to disorganised competition among the employers or the workers themselves, or between one sex and another, or a decrease arising from the competition of another district, and which might be met by a mutual understanding and agreement between employers and employed and a slight alteration in the system of production—which last is, I hope, the case of the Glasgow textile workers.

Finally, I think it must be obvious that all efforts to improve the position of the workers in any industry is so much labour lost when the industry itself is disappearing wholesale. It is useless, as all trade-union experts know, to try to force up wages in the face of a falling market, or to struggle for a more just division of profits when profits themselves have reached the vanishing point. And, whatever difference of opinion may exist as to the proportion of profits that should go to capital and the proportion that should go to labour (and I may say I am one of those who would like to see a much larger proportion go to the latter than goes at present), I think all reasonable persons are agreed that wealth must first be made before it can be distributed. One is tempted to quote here that most practical of all culinary recipes which says we must first catch our hare before we discuss the cooking of it.

In relation to decaying industries, I have several times to-night referred to the possible functions of the organisations of capital and of labour working in conjunction in respect to these and

other points, such as Boards of Conciliation. I naturally approach this subject with much deference, conscious that I am speaking in an assembly of practical business men, but I have sometimes thought much might be done to further mutual interests and to foster better relations between employers and employed if some *rapprochement* could be established between such bodies as the Chambers of Commerce on the one hand, and the Trades' Councils and Trades' Unions on the other. Or, to extend it further, why should not the State take up the matter on a scale not possible to any private association, however powerful. I am of opinion that one of the most practical and important things the Government could do would be to institute a careful and systematic inquiry into the causes which operate in bringing about the decay of British industries, and how far the same are remediable, and, if not remediable, to give every facility for starting and fostering new industries. And I venture to think if the Royal Commission on Labour, instead of spreading its economic investigations over the enormous field which it attempted to cover in the time at its disposal, had confined it to some such points as this, much practical good might have resulted to our national commercial interests. It may be objected that this is a matter for individual enterprise rather than for Government consideration. I entirely differ from those who think so. The near future holds the prospect that thousands of our working men and women may lose the means for gaining their daily bread, and that the whole community will lose certain sources of wealth, and only here and there do we find a Chamber of Commerce and a representative labour body taking practical steps in the matter, and taking them conjointly. It seems to me that this is the very work with which every Government ought to concern itself.

Surely in the Board of Trade, the Colonial Office (and whatever differences of opinion may exist on purely political questions, there can be only one opinion as to the practical business ability of the heads of these), and in other State departments, we have all the machinery we need for economic investigations, for obtaining absolutely reliable information as to the position and development of industries here, and such information as to the conditions under which they are carried on in other countries, as would stimulate commercial enterprise at home and suggest new outlets for it, and which would make for a closer union of industrial interests between

Great Britain and her colonies and dependencies. Much might be done if various branches of these Government departments could be centralised and organised under a Labour Department, that would be, not only a registry of statistics, but a department entrusted with really constructive work, and acting in the collective industrial interests of the community.

I am not able, I am afraid, to adopt the programme of our socialist friends, nor to accept without question their panacea for all our social ills; but I feel that, in emphasising the responsibility of the State for the welfare and daily needs of the whole community, and in directing attention to the possibilities of State effort, they have contributed a most valuable principle to current thought and opinion.

And in this matter of guarding and fostering our national industries I do not speak in the interests of one class more than another—the interests of both employers and workers march together in this: it is the basis on which our whole national and social life rests.

Finally, one is glad to note that the new methods for dealing with the evils in our social and industrial worlds are based more on economics than on sentiment, and that they savour less and less of charitable effort directed towards the *results* of bad conditions, and more and more of scientific inquiry as to their *cause*.

"There is no wealth but life," says Ruskin, and every day is bringing us a clearer sense of the terrible waste of life's forces—mental, moral, and physical—that goes on around us, and which, once we have grasped it, makes the tragedy of the world for most of us. There is an ever-growing tendency to save what we can of this wasted force, a clearer recognition of how goodly a thing life in this world on its natural, human side may be to our fellow-creatures, when "full summed in all their powers," and how far a good material environment is necessary to sound mental and moral health. Starving the body is no longer considered to be the necessary accompaniment to feeding the soul; and it is, perhaps, to this renewed sense of the joy of life, this latter-day Pagan Renaissance, of which we catch frequent notes in our modern art and thought, that the democratic movement largely owes its growth.

With the age's increased sense of the value of the goods of this world has come the wish to give our fellow-men their due share of these, and, consequently, an increased importance to all questions

affecting the daily life of the people. The trend of modern politics sets strongly in the direction of social matters. Political reform is now recognised as holding the relation to social reform that the means do to the end, and politics, in its widest sense, is defined as "the science of human happiness." We have come to feel that "that nation is the richest which nourishes the greatest number of healthy, happy, human beings," and to work our way to this as our national ideal.

GRAHAM LECTURE.

VII.—*On Argon and Helium.* By Professor WILLIAM RAMSAY, Ph.D., F.R.S., University College, London, and a former Member of the Society.

[Delivered to the Society, 8th January, 1896.]

(WITH EIGHT PAGE ILLUSTRATIONS.)

IN beginning my lecture on this subject, it may not be inopportune to say a few words about the early history of air, seeing that what I have to deal with later on has reference to one constituent of the atmosphere of the earth, and to a constituent of the atmosphere of the sun and the stars. In the early history of air it was supposed to be an element; but the word "element" in those days did not always bear the signification which we now give to it. Sometimes it was used in the sense in which we now employ it, as a constituent of a compound substance, and sometimes it was employed in the sense of a quality or property of bodies. These two meanings were much confused. Some writers used the word in one sense, some in the other, and some mixed both senses in their writings. A summary of the creation of the world, according to the old idea, is given in a poem by Lucretius, "*De Rerum Natura,*" or "The Nature of Things," and I quote from him these lines, which seem to convey pretty nearly the ancient ideas concerning air—

> "Denique res omnes debent in corpere habere,
> Aera quandoquidem rara sunt corpora et aër,
> Omnibus est rebus circumdatus appositusque."

"The air surrounds and is in contact with everything, and is a constituent of all bodies, inasmuch as all bodies are porous or of fine texture."

These views met their first opposition from Boyle, who, in the reign of Charles II., published an essay, termed "Memoirs for a General History of the Air." Boyle's style is very discursive, but, fortunately, there is left to us an exact summary of his views regarding air. His words are—"I conjecture that the atmospheric

air consists of three different kinds of corpuscles : the first, those numberless particles which, in the form of dry exhalations or vapours, ascend from the earth, water, minerals, vegetables, animals, etc. ; in a word, whatever substances are elevated by the celestial or subterraneal heat, and thence diffused into the atmosphere. The second may be yet more subtile, and consist of those exceedingly minute atoms, the magnetical effluvia of the earth, with other innumerable particles sent out from the bodies of the celestial luminaries, and causing, by their impulse, the idea of light in us. The third is its characteristic and essential property—I meán, permanently elastic parts." Those were once the ideas of an able thinker concerning the very complex nature of air. I show you Boyle's portrait on the screen.

We come next in order of time (or rather contemporaneously) to John Mayow, whose portrait I also show you. Mayow was a medical man who practised at Bath during the Bath season. He was a native of Oxford, or, at all events, was educated there. His views were much more advanced than those of Boyle. He recognised that the air contained certain particles, as he called them, to which he gave the name of *nitro-* or *igneo-aërial* particles, or, as we may translate that term, *fire-air* particles. These particles were substantially what we now know as oxygen. He recognised that air was composed of two distinct things, one of which was capable of supporting combustion, while the other was left behind after the burning bodies had removed particles of the first kind. The portion which was left behind he termed mephitic air, or air injurious to life and incapable of supporting combustion. I am fortunate in being able to show you a portrait of Mayow. He died at the early age of 32 years. Had he lived, no doubt he would have anticipated by more than a century the discoveries of the great French chemist, Lavoisier. It must be remembered that Boyle did not accept Mayow's views, although he knew of their existence. He was 58 years of age when Mayow's tractate was published, and a man of mature years is sometimes not disposed to be very charitable to a young man of 32, who airs certain views which are subversive of all old doctrines, and which are supposed not to be supported by sufficient experimental evidence.

Later on, about the year 1720, we come to the third investigator of air, Stephen Hales. You will notice, perhaps, that all those names are English. The discoverers in connection with air, curiously enough, have been almost entirely of English or of

Scottish extraction. Hales was a clergyman who amused himself with botany and horticulture, and who made experiments with vegetables; and having noticed that they evolved air when placed under an air-pump, he experimented on it. In other ways he attempted to extract air from vegetables by distilling them, and having got what he supposed was air by that method, he distilled a great many other substances. He was very careful to give data showing the volume of air which he got from known weights of the substances distilled. After several hundred such experiments he wrote—"Whence it is reasonable to conclude that our atmosphere is a *chaos*, consisting not only of elastic, but also of inelastic air particles, which float in it, as well as sulphureous, saline, watery, and earthy particles." The word "sulphureous" must be understood in the sense of those days as meaning "capable of burning."

The first definite discovery as regards the nature of air was made by a Scotsman, a former Lecturer on Chemistry in Glasgow University, and subsequently Professor in Edinburgh University, Joseph Black. He applied heat to what was then a new compound, carbonate of magnesium, from which he got a particular kind of air, which we know now as carbonic acid gas, or carbon dioxide. He found that this new "air" was capable of being fixed in combination with alkalies or lime; therefore, he called it "fixed air." He made it very clear that this air was not of the same kind as ordinary atmospheric air. I think he may be said to have been the first to point out that it is possible to prepare different kinds of air, and that they are not all modifications of atmospheric air, but that they have as much right to be called separate substances as any substance which we can handle or touch.

After Black came one of his pupils, Daniel Rutherford, afterwards Professor of Botany in Edinburgh University, who, for his inaugural dissertation for the M.D. degree, as he states, by Black's advice, undertook researches into the residue which was left after a candle, or charcoal, or similar combustible bodies, had been burned in air. After burning charcoal, for example, he found that if air was shaken up with lime-water or with alkali, the fixed air was removed; and that having removed this fixed air, a residue was left. This residue we now know as nitrogen. It was recognised as differing from ordinary air, inasmuch as it would not support combustion; and as differing from fixed air or carbonic acid,

inasmuch as it was not absorbable by alkalies. The views of philosophers in those days were what we should now term "topsy-turvy," or reversed. It was imagined that bodies capable of burning gave up something during their combustion; it was not recognised that they absorbed oxygen from the air. It was supposed that they lost something of the nature of flame, and to that "something" was given the name *phlogiston*. It was the "principle of burning" which they lost by being burned, so that they were no longer capable of being burned. Rutherford noticed that such substances as charcoal, or a candle, or lead, when heated in air, became changed, and that they were no longer capable of burning, and he imagined that they had given to the air this substance, phlogiston, which they themselves had lost. Hence he called this residue, which was left after the candle was burned in the air, "phlogisticated air." This "phlogisticated air" is what we now know as nitrogen.

Passing from Rutherford, we come next in order of time to Joseph Priestley, who was born near Leeds, and who was a Unitarian minister in Birmingham for many years. His publications related chiefly to controversial subjects in the domain of theology, but in the intervals of writing his controversial pamphlets he amused himself in his laboratory. He was first led to make experiments by his neighbourhood to a brewery in Leeds. His church was just alongside the brewery, and after preparing his sermons he took exercise in the brewery, and experimented on the air which came from the vats. This led him to the investigation of various kinds of gases, and he was the first to succeed in isolating the gas oxygen; and recognising that it, too, was distinct from ordinary air, he imagined it to be *good air*, and his works are full of the "goodness" of that air—what would now be termed the percentage of oxygen in the air. He obtained oxygen by heating red oxide of mercury, and also red-lead. Thirty years before, Hales was content to compare the weight of the lead compound with the volume of the oxygen got from it; but he does not seem to have made any experiments as to whether this gas was a separate constituent, "better" than ordinary air. It was Mayow's igneo-aërial particles to which Priestley gave the name *vital air*. He was acquainted with Rutherford's work at the time, for he refers to his experiments.

Contemporaneous with Priestley was the Swedish chemist, Scheele. He made a great many experiments on oxygen, and it

is quite an intellectual treat to read an account of Scheele's work—it is so full and complete, and the matter is reasoned out from the beginning. The only fault one has to find is that Scheele is as much interested in proving the truth of certain ideas of his own in regard to *fire-air* as in showing that the air contains this substance.

We next come to the French chemist, Lavoisier, who was the first to combine all previous experiments, and to show that when a substance is burned it combines with one of the constituents of the air, gaining in weight thereby, and that it does not produce this supposed phlogiston. To that constituent Lavoisier gave the name which we now use, oxygen.

Then came Cavendish. He successfully recognised that the two chief constituents of the air could be made to combine with one another. He found that if electric sparks are passed through a mixture of oxygen and nitrogen, such a mixture as we have in atmospheric air, the two combine very slowly, and that the resulting compound can be absorbed by some alkali, such as caustic soda or potash. The nitrogen is gradually removed by this process, and it is necessary to add more oxygen than is normally present in air. To remove the whole of the added oxygen, after combination of all nitrogen, either one of the oxides of nitrogen was added, or phosphorus, both of which have the power of combining with the excess of oxygen, and so removing it. Cavendish made wonderfully accurate experiments by means of the very crude appliances of his day. He had an electrical machine turned alternately by himself and his assistant for more than a fortnight, and the sparks from this machine were passed through the mixture of gases, confined over mercury, along with a little potash. He was careful to explain, as the result of such experiments, that there was nothing else in air than nitrogen and oxygen, unless a very small residue, amounting to $\frac{1}{120}$th of the whole, was something different. I may read you his words:—"For this purpose I diminished a mixture of dephlogisticated and common air in the same manner as before, till it was reduced to a small part of its original bulk. I then, in order to decompound as much as I could of the phlogisticated air which remained in the tube, added some dephlogisticated air to it, and continued the spark until no further diminution took place. Having by these means condensed as much as I could of the phlogisticated air, I let up some solution of liver of sulphur to absorb the dephlogisticated air; after which only a small bubble of air emained

unabsorbed, which certainly was not more than $\frac{1}{120}$th of the bulk of the phlogisticated air let up into the tube; so that, if there is any part of the phlogisticated air of our atmosphere which differs from the rest, and cannot be reduced to nitrous acid, we may safely conclude that it is not more than $\frac{1}{120}$th part of the whole."

Cavendish was a very singular person; there is no oil painting of him extant. The portrait I show you on the screen is a reproduction of a caricature of him by a contemporary artist.

Dalton soon afterwards discovered that when one element combines with another it does so in definite proportions. This gave an impulse to chemistry, and put it on a numerical basis. These views were first given in detail to the world by a Glasgow chemist, Professor Thomas Thomson, who was for many years President of this Society. After Dalton had made his discoveries, chemists were largely occupied in determining atomic weights; and this circumstance and the progress of organic chemistry, I suppose, must have led chemists, especially those of Germany, away from the investigation of the simpler problems.

There are two ways of arriving at the atomic weight of a gaseous element. One is by combining it with something else, and finding the proportion in which it combines. Some experiments of this kind were made by the French chemist, Dumas. Starting with oxide of copper he deprived it of oxygen by means of hydrogen, and in that way he determined the atomic weight of oxygen with great accuracy. There is another way of solving this problem. It is to weigh a known quantity of oxygen, and to compare its weight with that of an equal quantity of hydrogen. It is thus possible to determine the atomic weight of oxygen compared with that of hydrogen. This has often been done.

But Lord Rayleigh, about ten years ago, was struck with the necessity of making more accurate determinations, and of improving on the results previously obtained. He therefore set himself to determine the relative weights of oxygen, hydrogen, and nitrogen —in fact, the weights of the common gases. Oxygen and hydrogen presented no particular difficulty; but in experimenting with nitrogen, he used atmospheric nitrogen, and also "chemical" nitrogen made from materials such as ammonia, nitrous oxide, or a nitrate. We frequently discussed the subject together. Four or five years ago I remember him asking me for a practical plan of obtaining nitrogen from purely chemical sources. It turned

out that the nitrogen thus obtained weighed somewhat less than the nitrogen contained in the atmosphere; not much less, it is true; it was about $\frac{1}{230}$th lighter. He published his results, and, curiously enough, very little attention was paid to them.

Some doubt arose in the minds of those who saw his paper as to whether the determinations were accurate. But with the quantities used, it was out of the question that such a mistake could have occurred,—that there would be $\frac{1}{230}$th of a difference between weights of the nitrogen of atmospheric air and chemical nitrogen. In the spring of 1894 we again discussed the question, and it was then beyond doubt that there must be some reason for this discrepancy. Lord Rayleigh was inclined to favour the view that chemical nitrogen contained something light, that it was not a single substance. I rather held the opposite view, that atmospheric nitrogen contained something heavy. Lord Rayleigh having been so kind as to give me permission to work on the subject, we each checked and corrected these surmises by means of other experiments, and these experiments led to the discovery of the new element which was subsequently called ARGON.

Towards the end of July, 1894, I was able to show about 100 cubic centimetres (or, say, two wine-glasses full) of Argon. At the same time, Lord Rayleigh (who had gone on a similar track) was also able to show a small quantity of the same gas. We had employed different methods to obtain this gas. This was his method:—He passed a powerful alternating electric current between two thick platinum rods, contained in a glass globe, inverted over a weak solution of caustic soda; the globe contained a mixture of air and oxygen, and the soda absorbed the oxides of nitrogen as they were formed. The rate of absorption has, under favourable conditions, reached 7 litres of mixed gases per hour; but in order to prevent the globe cracking from the intense heat, it was immersed in a deep vessel of water.

It was Cavendish's old method on a larger scale.

Lord Rayleigh's earlier experiments were made with apparatus like that shown in Fig. 1. (See at end of lecture.) Between the wires, D D, in the glass tubes, C C, a succession of electric sparks were passed into a mixture of air and oxygen contained in the test tube, A, standing over a solution of caustic soda in the jar, B.

In his later experiments on a larger scale, he made use of a glass globe, A (Fig. 2), containing soda-solution. G and H are the platinum wires, between which a powerful discharge from a

transformer was passed. To prevent the overheating of the globe it was enclosed with a sheet-lead casing, kept full of cold water.

A third modification, which yielded good results, is indicated in Fig. 3. Here, in the jar, B, a current of dilute soda-solution is injected by means of a pump into the tube, C, so as to form a jet on the top of the globe. By a suitable arrangement (not shown on the figure), the excess of soda-solution is returned to the pump, again to be forced into the globe, A. (D D are the glass tubes through which the electrodes, E E, pass.) This device keeps the globe cool, while giving a large surface for absorption.

My method consisted in causing the nitrogen of the atmosphere, freed from oxygen by passing air over red-hot metallic copper, to come in contact with red-hot magnesium turnings, as shown in Fig. 4. In the preliminary experiments, atmospheric nitrogen, contained in the gas-holder, F, was measured in the tube, E, dried by reagents in the tube, C D, finally freed from oxygen in B, a tube fitted with red-hot copper, and A, a tube fitted with red-hot magnesium turnings, served to extract the nitrogen. Experiments showed that nitrogen, thus treated, gained progressively in density. Experiments on a larger scale were therefore begun, in which atmospheric nitrogen was made to pass, as shown in Fig. 5, between two gas-holders, over absorbents of the same nature. After much nitrogen had been absorbed, a similar smaller apparatus (Fig. 6) was employed, so as still further to eliminate nitrogen, in which the argon was confined over mercury in the gas-holders, C and G. D, E, and F are absorption tubes, as before. The residue was approximately pure argon, of density 19 (oxygen taken as 16).

And lastly, in Fig. 7, an apparatus is shown, in which the gas drawn from the gas-holder, B, could be made to circulate continuously by means of a mercury-pump, A, over copper and copper oxide contained in C, drying materials in D, magnesium in E, until finally the reservoir, D, became full of pure argon, which could be drawn off and stored in the gas-holder, J.

These were the two plans of preparing this new gas, which forms about one per cent. of the volume of the air. More accurate experiments which have recently been made by one of my assistants, Mr. Kellas, show that air contains 0·923 per cent. of argon; or, to put it in another way, 10,000 parts of air contain about 92 of argon. If this referred to nitrogen, the mixture of nitrogen and

argon which we have been in the habit of calling nitrogen contains about 1·186 per cent. of argon. Other experiments which have been made by M. Schlœssing produce almost the identical number, 1·183, so that there can be very little doubt that there are, as I have said, about 92 parts of argon present in 10,000 of air.

Many attempts have been made to produce compounds of argon. About two months were spent in vain endeavours. Most compounds and elements were offered to argon in the hope of tempting it to combine, but without effect—nothing happened. Every experiment has been negative up till now; no compound of argon has been obtained, unless we should except some compounds which have been produced by the present Foreign Minister of France, M. Berthelot. By passing sparks through a mixture of argon and benzene, he obtained a new substance, a sort of brown resin. That resin, when heated, gives up its argon; but any one who is in the habit of forming compounds will know how unpromising a material a brown resin is. I am myself inclined to believe that this resin is more of the nature of a solution of argon than a compound. Argon is somewhat soluble in water, and I think it is carried down by sparks and entangled in some way in this gum. I shall show you that it is possible to entangle nitrogen in the same way with platinum.

It was, of course, of interest to determine whether or not argon plays any part in the animal and vegetable economy, and the most practical way of determining this was to obtain nitrogen from some animal and vegetable source, and test for argon in the nitrogen. For that purpose a quantity of peas was taken, and the nitrogen extracted by a well-known process, and after sparking it down and removing the nitrogen by combining it with oxygen, absolutely nothing was left; so that there is no residue, no argon in vegetable matter. Two mice were sacrificed on the altar of science. They were dried, and the nitrogen obtained from them was sparked down in the same way. It may interest medical men to know that the nitrogen in a mouse, —at all events, a dry mouse—was one-eleventh per cent. of the total weight of the animal. Again there was an absolutely negative result, no trace of residue was obtained, so that neither animals nor vegetables appear to contain any argon.

It was necessary, in searching for argon, to try all possible clues. Mr. Miers, late of the British Museum, was so kind as to tell me of some curious experiments made by Dr. Hillebrand,

one of the chemists of the Geological Survey of the United States. Dr. Hillebrand had investigated different minerals containing uranium, and he found that these minerals when heated alone, or when boiled with weak vitriol, gave off a gas which he supposed to be nitrogen. It was very unlikely that the mineral after this treatment with sulphuric acid should give off nitrogen; and I obtained some clèvite, in the hope that, if this substance turned out to contain argon, it would give a clue to a method of forming other compounds, and that it would be worth while trying other minerals as well as those containing uranium.

On investigation, the gas turned out not to be argon at all. The mineral gave off a gas; and that gas on being purified in the usual way, gave a spectrum which was not that of argon, but a different one. The spectrum showed a brilliant yellow line, which I took to be the line of sodium, and I should like to show you the appearance of this spectrum. [Spectroscopes handed round.] You will notice that in the lower tube this yellow line coincides very nearly with the yellow line in the upper tube, which is much more brilliant. In the upper tube we see the spectrum of this new gas. The lower tube contains argon, and what you look at is the spectrum of argon. Wires pass through the glass, and these wires are connected with fair-sized lumps of commercial magnesium, in which some sodium is present as an impurity. My idea was that the gas would be by this means purified from nitrogen. You will see, therefore, that the yellow line on the spectrum in this lower tube is the yellow line of sodium. This was the actual tube that I used in comparing the spectrum of the new gas. Both spectra were seen at the same time; but with a more delicate spectroscope, I noticed that the yellow lines did not coincide. I thought there was something wrong with the spectroscope, and I took out the lenses and polished them. After stupidly wasting about ten minutes, I found that the lines still did not coincide, and that there was no use in expecting them to coincide, and then, for the first time, I recognised that this was a new substance, giving a new spectrum.

Most chemists are aware of certain work which has been carried out by Professor Lockyer and Professor Frankland on the spectrum of the atmosphere of the sun, or, as it is called, the chromosphere. Professors Lockyer and Frankland noticed the appearance of a line similar to this yellow line in the spectrum of

the chromosphere, and, having occasion to mention this line frequently, they gave it the name Helium—an appropriate name, for this line had never been seen before in the spectrum of any terrestial substance,—the word being derived from the Greek name for the sun, *helios*.

Mr. Crookes happened to have a very accurate spectroscope, and I sent him a tube of this gas. Shortly after measuring its wave-length, he telegraphed to me that the new line was coincident in length with the line of helium which had previously been discovered by Professors Lockyer and Frankland.

The search, then, for compounds of argon led to the discovery of this new gas, helium. Many minerals were investigated in order to see whether they contained helium, and it turned out that a great many contained it. It is found in monazite, which is mined in large quantities in the United States, and is used for making mantles for those incandescent gas burners now so largely in use. The helium so used escapes by the process of manufacture, and experiments are being made to see whether it cannot be collected. I have here some of the substance clèvite, the mineral from which the gas was obtained. Here, again, is another mineral, bröggerite; and here is another, hjelmite; and here is clèvite, the original mineral from which we obtained this gas for the first time.

One of the first properties of such gases to be investigated is the density, and careful experiments show the density of argon to be close upon 20 times as great as that of hydrogen, whereas helium is only $2\frac{1}{5}$ times as heavy as hydrogen. Another property is the expansion of the gases—how much they increase in volume on being heated through one degree of temperature. There is nothing particular to say in this respect about these gases. Their expansion is like that of other gases, such as oxygen and hydrogen: they expand normally.

Another question is whether they can be reduced to the liquid state or not. That experiment I was unable to carry out. I made some experiments, but want of apparatus made it impossible to cool the gases to a temperature lower than –80° centigrade. A large sample, therefore, was sent to Professor Olszewski, of Cracow, who is well known by his researches in liquefying gases, and he was successful in liquefying argon. You will see the point of liquefaction of some of these gases on the wall-table. Nitrogen boils at –194°; argon at –187°; oxygen at –184°·7. Nitrogen freezes at –214°; argon at –189°; oxygen up till now has not

LIQUEFACTION POINTS, &c., OF ARGON AND SOME OTHER GASES.

NAME.	Critical Temperature.	Critical Pressure.	Boiling Point.	Freezing Point.	Freezing Pressure.	Density of Gas.	Density of Liquid at Boiling Point.	Colour of Liquid.
		Atmos.	Degrees.	Degrees.	Millims.			
Hydrogen (H_2)	Below. −220·0	20·0	?	?	?	1·0	?	Colourless
Nitrogen (N_2)	−146·0	35·0	−194·4	−214·0	60	14·0	0·885	„
Carbonic oxide (CO) - -	−139·5	35·5	−190·0	−207·0	100	14·0	?	„
Argon (A_1) -	−121·0	50·6	−187·0	−189·6	?	19·9	about 1·5	„
Oxygen (O_2) -	−118·8	50·8	−182·7	?	?	16·0	1·124	Bluish
Nitric oxide (NO) - -	− 93·5	71·2	−153·6	−167·0	138	15·0	?	Colourless
Methane (CH_4)	− 81·8	54·9	−164·0	−185·8	80	8·0	0·415	„

been frozen. Since this table was drawn up the boiling point of hydrogen has been determined as −245°, but it has not yet been solidified. Later, I sent to Professor Olszewski a quantity of helium, and he exposed it to the same degree of cold which he found capable of liquefying hydrogen, but without effect, and helium has not as yet been liquefied.

It is interesting to inquire as to the occurrence of argon and helium in nature. One source which yields both gases is mineral waters. Water from some springs at Droitwich, which comes from very deep strata, contains argon in considerable quantity, in larger quantity than is present in ordinary water or air. But the most remarkable results have been got by Lord Rayleigh, who has found helium, as well as argon, in the Bath waters. The apparatus with which he extracted the gases is seen in Fig. 8. The water is led in through the tube, E, F, G, into the tin vessel, A, heated below by a burner. The gases escape through the tube, I, while the water runs out through B, C, D, after having given up its gas. A French chemist, M. Bouchard, of Paris, has also found in certain sulphur springs at La Raillère, in the Pyrenees, argon in considerable quantity, and also helium. M. Moureau has lately found at Maizières springs which contain lithium, springs like those that occur in England, in Cornwall, containing quantities of gas; and about one-tenth or one-fifteenth of the gas which bubbles up from these springs consists of a mixture of argon and helium.

Then, some time ago, I made experiments with meteoric iron, and I will show you the gas from a meteorite in which the spectra of both argon and helium are visible. This is particularly interesting, because here we have an extra-terrestrial source of argon,—in fact, so far as I am aware, the only extra-terrestrial source. The spectrum of argon has never been observed in the fixed stars or in the sun, while the spectrum of helium is common in the light from many of the fixed stars. Here is a meteorite which gives off a gas mostly consisting of hydrogen, but which contains a considerable quantity both of helium and argon. The argon hues are most easily recognised towards the red end of the spectrum, and the helium, yellow and green, can also easily be seen.

One of the interesting properties of all gases is their specific heat—the amount of heat required to raise a given weight of the gas through a given temperature. Different substances require different amounts of heat. Now, in the case of gases, this is specially interesting, because it is possible by this means to distinguish between the different kinds of motion of the particles which constitute the gases. It is difficult to render this plain to those who have not been working at the question. But just imagine that particles of gas have two kinds of motion, a motion through space from one place to another; that these particles sometimes occur joined in couples—in a crude sort of way resembling dumb-bells; and that a number of particles collected together, besides moving from place to place, rotate round each other, or vibrate in connection with each other, or something of that sort, though the actual character of the motion is not known. It is possible by determining the specific heat of the gas to make out whether the particles of the gas possess motion through space alone, or whether that motion through space is accompanied by such rotatory or vibratory motion.

Now, it turns out that the molecules or particles of argon and helium possess the translatory motion through space alone, but that they are devoid of the rotatory motion. If that is so, the particles are not complex, for it is impossible for one perfectly smooth and frictionless sphere to rotate in that manner. For rotation of this kind, two or more particles must be joined together. It follows, then, that the particles are single; they are not united together in couples, triplets, or more complex groups. Now, a compound is necessarily composed of more than one particle; there must be at least two particles or atoms to form a compound. If

these gases occur in single particles, they are not compounds; they must be elements and, therefore, for this reason, it is concluded that argon and helium are not compounds, but elements.

And now an interesting question arises—What are the atomic weights of these elements? If argon consists of single atoms moving through space, its density should be one-half its atomic weight. Now, it is 20 times as heavy as hydrogen, and its atomic weight should be 40. But it so happens that there is another element of the same atomic weight, namely, calcium—the metal of which lime is the oxide. We know of no other case in which there are two elements of the same atomic weight, except that of cobalt and nickel, which possess nearly the same atomic weight; and on the face of the matter it looks improbable that calcium and argon are related to each other like cobalt and nickel.

One way out of that difficulty is to suppose that argon is not a single element, but a mixture of elements, and that its supposed atomic weight represents not its real atomic weight, but the mean atomic weight of the two elements of which the mixture may consist. You may ask me what is the proof of that. If there is no proof, there is, perhaps, a presumption, and I shall try to demonstrate this experimentally. It is possible to change the spectrum of argon from red to blue. I show you this tube. I shall now alter the spectrum. You will notice that it occasionally flashes blue and then turns red. When the Leyden jar is interposed, the light is blue; when it is removed, it is red. There is no other gas which shows this peculiarity in its spectrum to the same extent; and it may be that this shows the spectrum of two kinds of argon. It may be that one constituent is shown up by the blue lines, whereas some other constituent is shown by the red lines. Then, again, the same question may be asked as regards helium—Is it possible to alter the spectrum of helium? And here, again, the answer is in the affirmative. It is possible. The helium which I have been showing is helium at a fairly high pressure. When I say a fairly high pressure, I mean a pressure of about $\frac{1}{300}$th of that of the atmosphere; the pressure in the tube that I now show you is not quite so high, but you will see the yellow line clearly, and the brilliant red and green lines. I am going to put on a tube which contains helium at a much lower pressure, about $\frac{1}{30,000}$th part of the atmospheric pressure. This tube will show the green line very much brighter, in addition to the bright yellow line. They are now about equal in brightness,

but you will notice the difference in colour. Instead of having a brilliant yellow, it is now of a bluish-green colour. This is produced by changing the pressure alone. The green is specially brilliant, but the yellow line is not so remarkable. This is not because of the separation of one constituent from another, but because of the alteration of the pressure.

You may notice that the tube gets blackened if the current is allowed to run for a certain time between platinum poles. The platinum carries off the helium with it, and the tube becomes empty. This tube when heated will give off some gas, showing a brilliant green line. Now, it is possible to clear the whole of the helium out of the tube in that way, and it is also possible to fractionate and separate it into parts by heating the platinum again. Experiments have been made to see whether different fractions of the gas obtained by heating the platinum have the same spectrum: whether some portions given off at a low temperature are richer in green than those separated at a higher temperature. It might thus be possible to separate helium into two different kinds of gas. But experiments of this kind give negative results; the spectra of both fractions are identical. These results show at least that it is possible that both argon and helium may be mixtures, but it is not proved. We are without data on the subject.

I have yet another experiment to show you to illustrate another very remarkable property of this gas which has not yet been made public. [Experiment.] You will see here that a spark which will pass only a short distance through air shoots across, sometimes inside and sometimes outside, the tube; in fact, the little tube which contains air will with difficulty allow the spark to pass through it. I will repeat the same experiment, using not air, but hydrogen. You will see it is possible to pass the sparks through a greater distance—about double—with hydrogen. The sparks are coloured red, because red is the predominant colour in the spectrum of hydrogen. Let us put in the helium tube and see the difference. This tube contains helium at atmospheric pressure. You will see that the sparks pass through it very readily. It follows from this that helium must be a very good conductor of electricity. Now, we know very little, indeed almost nothing, of the reasons why gases convey electricity, and I think this opens up an interesting field for future inquiry. Here is a gas which conducts electricity much better than any other

gas. Argon conducts better than hydrogen—about twice as well. This opens up the question why gases conduct electricity, and I have no doubt valuable results will be obtained from this discovery.

Another set of experiments, bearing pretty nearly on the same point is this: In what proportion can the one gas be recognised in the spectrum of the other? You have seen the red line in argon. How much argon can be seen in helium? How much argon can be recognised in nitrogen? How much nitrogen must be added to argon to cause the red lines to fade out? Experiments like these have been begun, and they are very interesting. I am at present engaged in them, and the results are indeed curious. It is astonishing how the different gases affect each other. It may be that these lines determine their relative conductivity for electricity. For example, if 10 per cent. of helium be added to hydrogen, the helium lines fade out entirely. On the other hand, a very minute quantity of hydrogen can be recognised in helium—about 1 part in 100,000. In a mixture of helium with nitrogen, 10 per cent. of helium is barely visible. Helium is invisible in argon when the mixture contains 25 per cent. of that substance, whereas argon is visible in helium, if the mixture contains no more than six ten-thousandth parts of that body, and so on. If the visibility of such spectra depends upon their conductivity, then we have the means of determining the relative conductivity of these gases for electricity.

Another very interesting question has regard to the distribution of helium in the stars. It has been found that helium exists in the sun's chromosphere. It also exists in a great many of the fixed stars. A number of the stars in the constellation of Orion are distinguished by dark lines, which appear to be bright in the spectrum of the nebulæ. In the spectrum of Orion many of these lines are coincident with the lines which you observe in the spectrum of helium, so that obviously the stars in that constellation contain helium. Now, some of the stars show the green line of helium very much more brightly than the yellow line; and as we know that the green line can be brought out by lowering the pressure, we have here the means, I think, of ascertaining what is the actual pressure of the gas in the nebula of Orion. It must be exceedingly low. The gases must be extraordinarily attenuated, probably about one hundred-thousandth part of the atmospheric pressure. We have here a new means of investigating the condition of these nebulæ.

In choosing a topic for this lecture I hesitated between selecting a subject which a Vice-President of this Society about sixty years ago, Thomas Graham, my father's old teacher and intimate friend, had made classic—namely, the passage of gases through metals,—and of telling you the results which I had obtained in repeating and extending his researches; or in choosing the subject which I have brought before you. Such a lecture would have been in close relation with the extraordinary recent developments of chemical theory introduced by Van't Hoff, with the collaboration of Raoult, Arrhenius, Ostwald, and Nernst. But your Council decreed otherwise. Had this lecture been delivered at a later date I should have had, I hope, to inform you of the results of applying Graham's methods of research to determine whether or no these new gases are simple elements or mixtures of elements. Graham's method of diffusion was successfully applied to the nitrogen of the air by my colleague, Lord Rayleigh, and we regarded it as the most incontestible proof that we could bring forward that argon was a constituent of the air, and was not being manufactured during the process of its extraction. But up till now I am unable to say whether or no the process of diffusion applied to argon or helium will reveal them as single elements or mixtures. I am also unable to tell whether or no these gases pass through metallic septa. Certainly they are not absorbed, save by the "splashing" process already described. The lecture has, therefore, been somewhat egotistic, or, I rather hope, "dualistic;" but it is unnecessary to say that in further researches the beautiful methods of our master, Graham, will have to be employed before we can affirm that we have acquired a competent knowledge of this fascinating subject.

In conclusion, I have to thank you warmly for the attentive way in which you have listened to a lecture in which, I fear, illustration by experiment has been only too deficient. When gases, or, indeed, any other substances, are idle, it is difficult to show experiments of an elaborate character. To defend myself, I must take shelter behind the substantial bulwarks of argon and helium. I have also to thank you for the great honour you have done me in asking me to deliver the "Graham Lecture."

NOTE: *Added 13th July.*—Experiments made by Graham's plan appear to show that, while argon is a single substance, helium is a mixture. W. R.

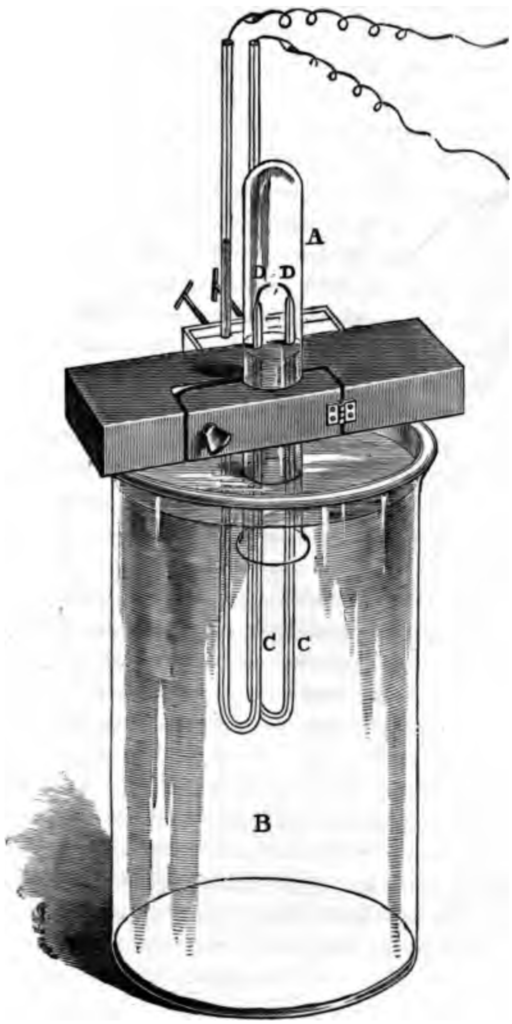


FIG. 1.

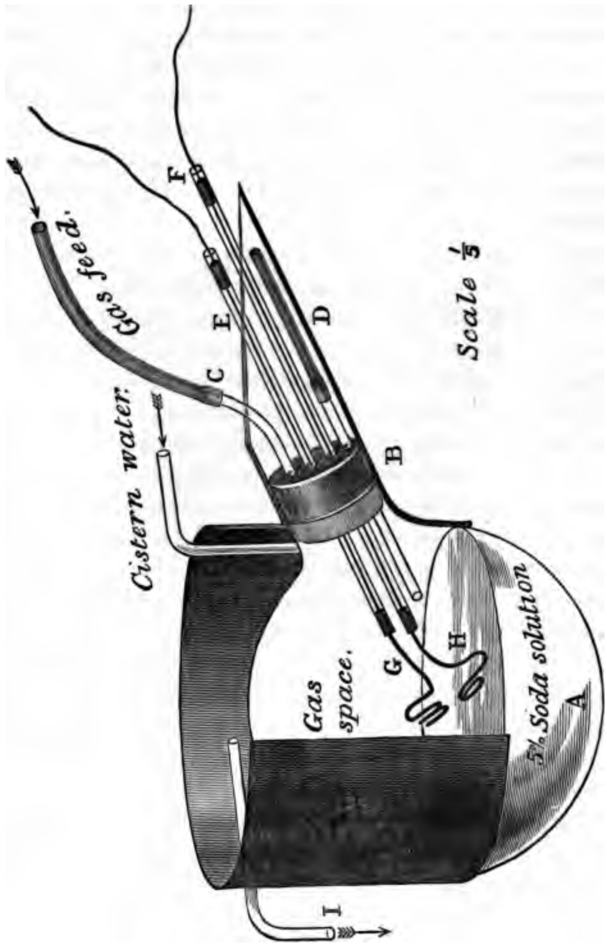

Gas feed.
Cistern water.
C
E
F
D
B
Scale 1/5
Gas space.
G
H
5% Soda solution
A
I

FIG. 2.

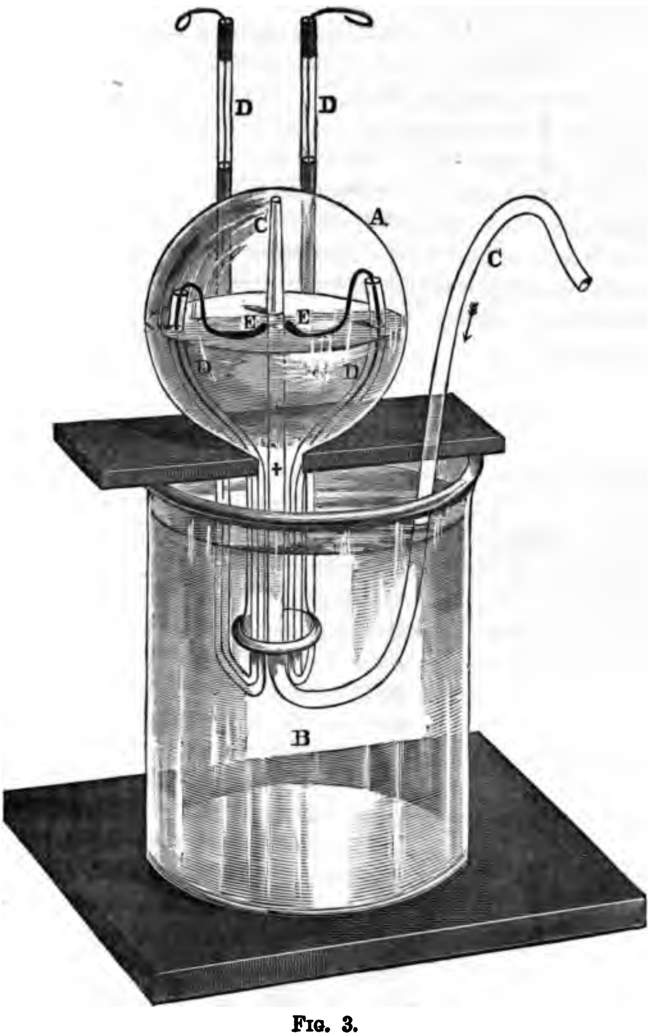


FIG. 3.

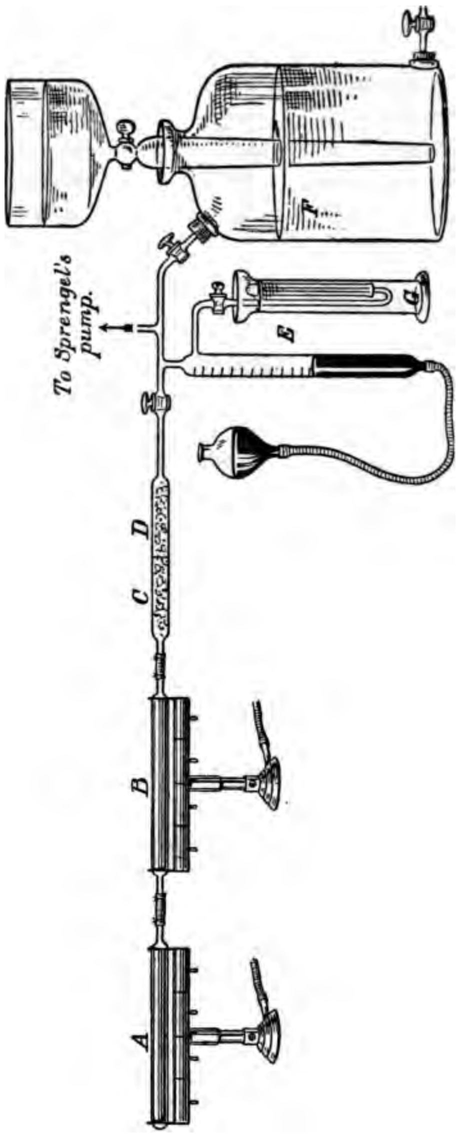


FIG. 4.

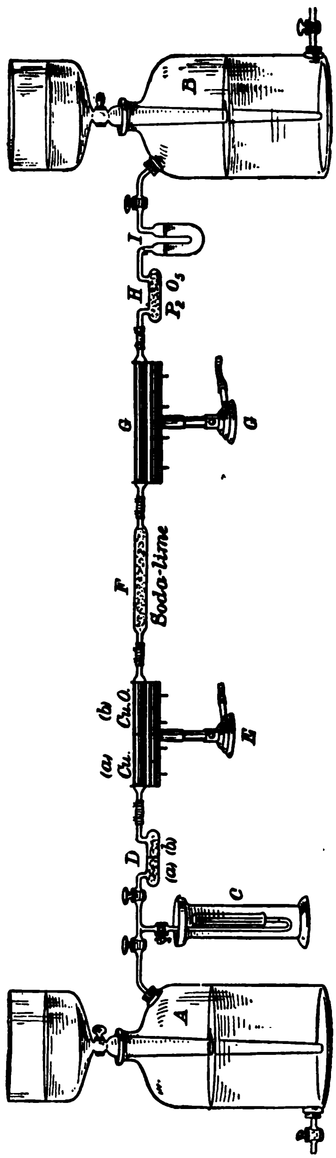


FIG. 5.

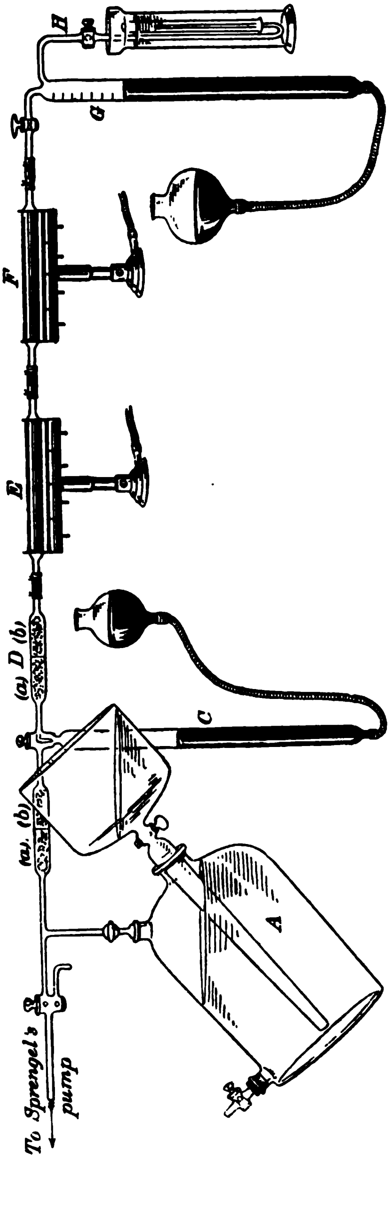


Fig. 6.

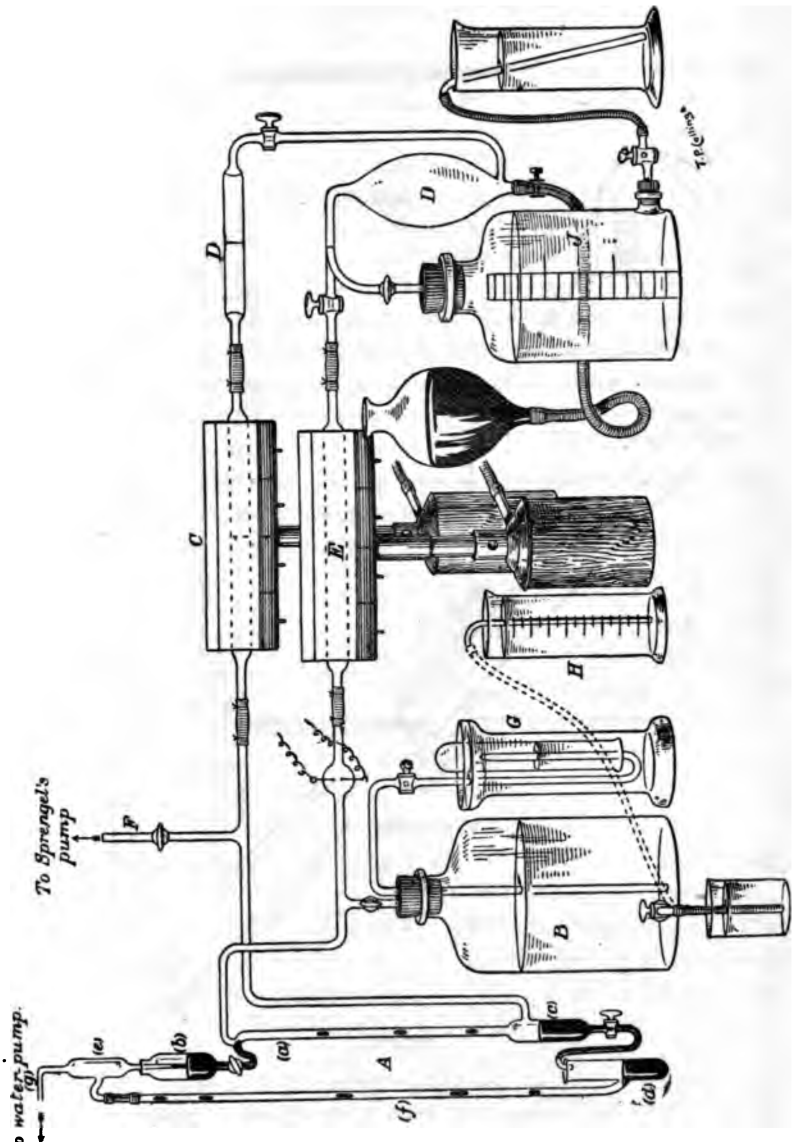


FIG. 7.

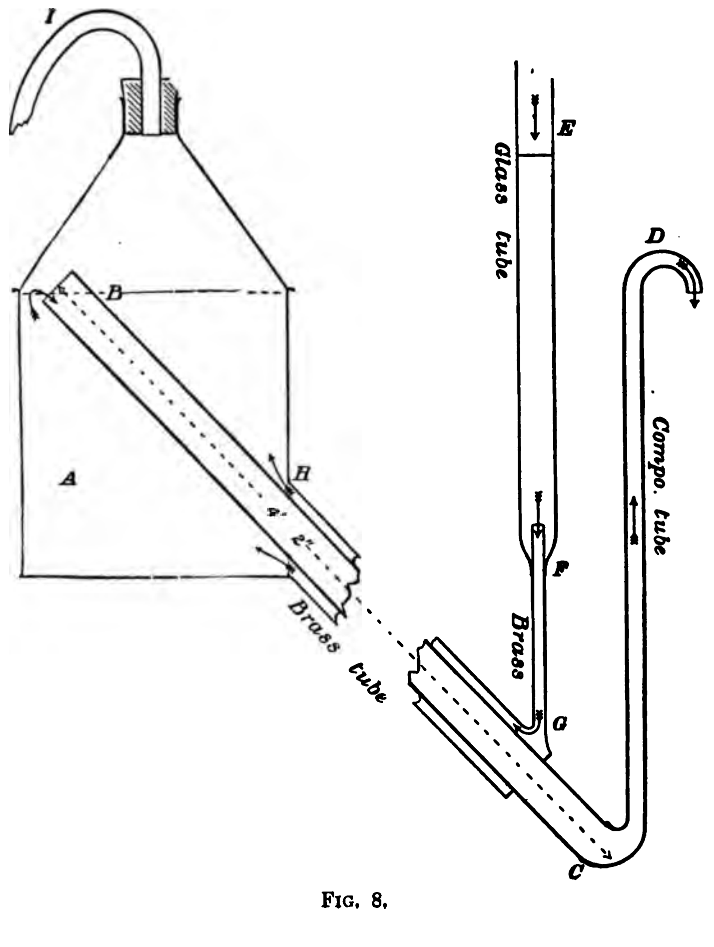


FIG. 8.

VIII.—*Domestic Applications of Electricity.* By W. B. Sayers, M.Inst.E.E.

[Summary of Lecture delivered to the Society, 15th April, 1895.]

Mr. Sayers said that the passage of a current of electricity through a conductor is attended by three principal phenomena :—

First.—A magnetising force is generated which encircles the conductor or wire, the direction of which is at right angles to the axis of the wire.

Second.—The conductor or wire experiences a force of translation when placed in a magnetic field.

Third.—The conductor or wire becomes heated.

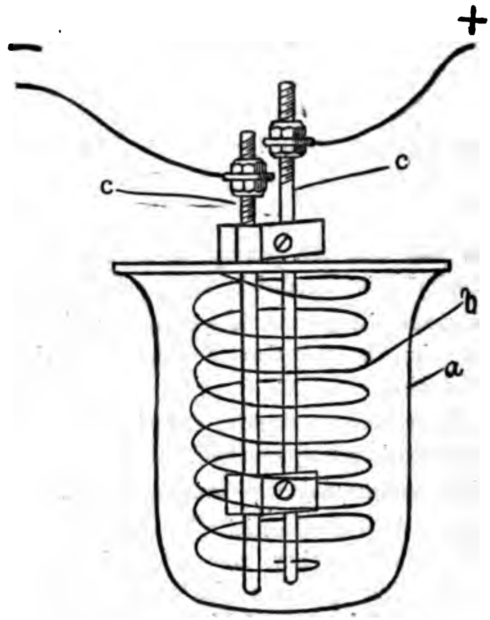
In the applications of electricity to domestic uses, of which the lecturer wished to show some examples, all these three phenomena attending upon a conductor conveying a current of electricity are called into requisition. Before going on to the application of these properties, it would perhaps be interesting to show one or two simple experiments illustrating them.*

Experiments.

A conductor, consisting of a fine platinum wire, was heated by the passage of an electric current derived from the Corporation mains. It was first made red-hot, and subsequently fused. The application of the heating of a wire to the boiling of water was next illustrated by means of a piece of apparatus consisting of a glass beaker (*a*) in which was a coil of high-resistance (platinoid)

* The experiments illustrating the first and second phenomena were not made, owing to the apparatus which was expected not having come to hand, but the reader is referred to the author's previous paper "On Dynamo Electric Machinery," in which these experiments are described, read before the Society, 21st March 1894. (See *Proceedings*, Vol. XXV., p. 196.)

wire (*b*), supported by two copper rods (*cc*), which formed the terminals. (See accompanying illustration.)



These terminals were connected to cables leading through instruments, and controlling resistance, to the Corporation mains. On turning on the current the platinoid wire was heated to such an extent that, had it not been submerged in the water in the beaker, it would have been fused. Raising the coil out of the beaker for a moment, the steam from the wire, accompanied by hissing noise, showed that the temperature of the wire passed that of boiling water almost instantly on removal.

By means of an ammeter and voltmeter of Lord Kelvin's type, kindly lent by Mr. James White, the current flowing and the voltage were read off. It was then found that the current was 40 amperes and voltage 97, the cost of the current being used was, therefore, at the rate of nearly two shillings per hour. The reason of such excessive cost was that, in such an experiment, it was not practicable to employ a long length of very fine wire, which would be necessary in order to use the whole of the 100 volts pressure of the Corporation supply. It was necessary to

use a moderate length of wire, stiff enough to support itself, and this was only adapted for a pressure of about 20 volts. In consequence of this, $\frac{4}{5}$ths of the power was being wasted in a large controlling resistance, and the cost of the energy spent in heating the water in the beaker was at the rate of about fivepence per hour. The water, however, would have boiled in a very few minutes.

The application of the hot wire to cooking operations was illustrated by means of apparatus kindly lent by Messrs. Crompton & Co., of London and Chelmsford. The apparatus included—

Cooker.	Griller.
Kettle.	Flat iron.
Frypan.	Heater for curling tongs.

These several articles were connected with the Corporation supply terminals.

The kettle, when filled with cold water, took twenty minutes to boil, and required 320 watts. Thus, with the Corporation price of 6d. per unit (Board of Trade unit = 1,000 watts per hour), the cost of boiling the kettle was—

$$6 \times \frac{320}{1000} \times \frac{20}{60} = 0{\cdot}63 \text{ penny};$$

or with the price paid for electricity for power and such purposes in Edinburgh, that is to say, $3\frac{1}{2}$d. per unit—

$$3{\cdot}5 \times \frac{320}{1000} \times \frac{20}{60} = 0{\cdot}365 \text{ pence};$$

or, say, one-third of a penny.

Potatoes were boiled in the cooker. This required 300 watts; the time was 42 minutes (22 minutes boiling water and 20 minutes for cooking), and the cost was—

$$6 \times \frac{300}{1000} \times \frac{22+20}{60} = 1{\cdot}26 \text{ pence};$$

or in Edinburgh—

$$3{\cdot}5 \times \frac{300}{1000} \times \frac{22+20}{60} = 0{\cdot}74 \text{ penny}.$$

A chop was next cooked upon the griller, and this and the frypan each required about 420 watts. The time for cooking the chop

was not taken, but it did not exceed 10 minutes. The cost, therefore, was—

$$6 \times \frac{420}{1000} \times \frac{10}{60} = 0{\cdot}42 \text{ penny};$$

or with Edinburgh power rates—

$$3{\cdot}5 \times \frac{420}{1000} \times \frac{10}{60} = 0{\cdot}245 \text{ penny},$$

or about one farthing.

The most striking feature about the cooking utensils was the entire absence of dirt; the vessels were as clean outside as inside, and might always be kept so. As the heat was generated in a wire concealed in the double bottom, there was neither fire nor flame, and, of course, no blackening of any part of the utensil, and the cooking might be conducted on an ordinary table without the slightest inconvenience, there being no dirt whatever.

In illustration, the applications of the first two phenomena mentioned at the beginning of this summary, a Blackman air propeller and a table fan, kindly lent by Messrs. Mavor & Coulson, were exhibited in operation. Both of these were driven by electric motors. The electric motor consisted of an arrangement in which the magnetic field generated by a current flowing in a coiled conductor, acting upon a mass of iron (known as the "field magnet"), which was thereby powerfully magnetised, producing a far stronger magnetic effect than could be obtained with the helix or coiled conductor alone. Having obtained a powerful magnetic field, the next thing was to take advantage of the force of translation experienced by a conductor carrying a current of electricity. This was done by means of the armature, which is the name usually given to the moving part of the motor. The armature consisted of a cylindrical mass of laminated iron, upon which was wound a helix of insulated copper wire, and the helix was "re-entrant"—that is to say, its ends were joined together so as to form an endless helix. When in position in the field magnets, the iron cylinder formed a far easier path for the magnetism or "lines of force" than existed when the space between the poles of the field magnet was filled with air. Consequently, the iron cylinder was powerfully magnetised, and the intervening space between the polar faces and the armature cylinder was the region of a very powerful magnetic field. The wires of the helix passed through this magnetic field, and when a current was passed

through the helix, the connections being made to opposite points so that the current divided into two parts—one flowing each way round the helix, the result was that over one-half of the cylinder the current in the surface wires would be in one direction and in the opposite direction in the other half; and when placed in a magnetic field the two oppositely-directed forces constituted a "torque" or rotatory force, which caused the armature to revolve. By means of the commutator, which consisted of a number of insulated plates connected to the helix at equal intervals all round, connection was made through stationary brushes to succeeding points on the helix in such a way that the point of connection was continually being shifted forward in the direction of rotation, which prevented a position of equilibrium being arrived at, and continuous rotation was the result.

The Blackman air propeller was put in operation. At a speed of 800 revolutions per minute, according to the makers, it moved 6,000 cubic feet of air per minute, and required a current of 4 amperes, at 100 volts, to drive it. At the price now charged in Glasgow, this air propeller, when working at full capacity, therefore, cost per hour—

$$6 \times \frac{400}{1000} = 2{\cdot}4 \text{ pence.}$$

IX.—*The By-Products of the Blast Furnace.* By A. HUMBOLDT SEXTON, F.C.S., F.R.S.E., Professor of Metallurgy, Glasgow and West of Scotland Technical College.

[Read before the Society, 1st April, 1896.]

(WITH PLATE I.)

THE important part which the blast furnace plays in the industries of the West of Scotland renders it quite unnecessary to apologise for bringing any matter connected with it before this Society.

It was not in this country that the blast furnace was invented, nor was it in this district that the Scotch iron trade had its birth; but it was here that it reached its greatest development, and here were originated some of the most important improvements in working it—improvements which not only benefited the whole world, but raised the West of Scotland into the position of the premier iron-producing district in the world. Though, owing to changed conditions, other districts have now surpassed her, the manufacture of iron is still of vast importance, even if it may not still be regarded as being the most important of her industries.

The tall, not ungraceful, blast furnaces which are dotted over Lanarkshire and Ayrshire are familiar to all, yet few, except those actually connected with them, realise what powerful engines of production they are, or the vastness of the quantity of material which they consume and reproduce in another form.

Large though these blast furnaces are, and in spite of the enormous increase in size which has taken place during the last forty years, they are small when compared with those used in some other districts. The largest furnaces here are little over 60 feet in height, while those of Cleveland are over 90 feet, and in some cases over 100 feet high. This difference is not due to any lack of energy on the part of the Scotch ironmasters, but to the fact that nature has handicapped them by supplying a fuel, which is good enough in many respects, but which at a high temperature is not strong enough to bear the enormous weight of a very high column of material.

A modern furnace, as used in this district, is about 60 feet high and 12 to 18 feet in diameter at the widest part. Once the furnace is filled up it is kept running night and day until it has to be stopped for repairs, which may be after running from ten to fifteen years, though, unfortunately, all furnaces do not stand such a long time. While at work the furnace is kept full of material, and as the liquid iron and slag are drawn out at the bottom, coal, ore, and flux are added at the top.

Solid materials are put in at the top, but, excepting the small quantity of dust accidentally carried over, nothing can escape except liquid substances, which are tapped out at the bottom, and gases, which escape at the top, so that all the charge must be either liquefied or gasified.

Suppose a furnace in operation, working satisfactorily, and producing 350 tons of iron per week. This is about what is made in this district, though in others very much larger outputs are obtained; but the proportions are almost exactly the same, whatever may be the actual amount of iron made. A weekly "make" of 350 tons will be just about two tons per hour.

In order to see what goes on in the furnace, it will be simplest to draw up a sort of balance sheet, on which the material which has to be put into the furnace will be its income, and that which comes out will be its output. As, when the furnace is working steadily, what goes in must exactly equal that which comes out, the two sides of the account must exactly balance. If the income were greater the furnace would soon become so full that it could hold no more, and if the output were greater it would soon empty itself.

The income each hour will be—

Iron ore (40 per cent. of iron), - -	5 tons.
Limestone, - - - - - - -	1 ,,
Coal (say, 60 per cent. of carbon), - -	$3\frac{1}{4}$,,
Air (say), - - - - - - -	12 ,,
	$21\frac{1}{4}$ tons—

and this will yield us two tons of pig-iron, which is $\frac{2}{21}$ or just about 9 per cent., so that of the 21 tons of material put into the furnace the amount regained is only two tons, while the other 19 tons are by-products.

The accompanying plan shows how the materials are distributed. The iron, 1, of the ore appears in the output as pig-iron; and the substances numbered 2, 5, 6, 8, and 9 form the gases of the output, while those bearing the numbers 3, 4, and 7 become the slag on the right-hand side of the plan.

Income.		*Output.*
Iron Ore—	5 tons.	
1. Iron,	2 ,,	Pig-iron, 2 tons.
2. Oxygen,	·86 ,,	
3. Earthy matters,	2·14 ,,	Slag, 3·02 ,,
Limestone—		
4. Lime,	·56 ,,	
5. Carbon dioxide,	·44 ,,	Gases, 16·23 ,,
Coal—	3½ ,,	
6. Carbon,	1·95 ,,	
7. Ash,	·32 ,,	
8. Gases,	·98 ,,	
9. Air,	12¼ ,,	

The by-products are of three kinds—

(1) The slag, which is drawn off in the liquid condition.

(2) The gases, which escape at the top.

(3) Accidental products.

The amount of slag produced varies much with the richness of the ore, the amount of limestone which has to be used as flux, and the amount of ash in the coal. In the case described, the material would amount to about 528 tons per week, but it may be much more, or in some cases considerably less. Thus an enormous amount of material has to be disposed of, for, it must be remembered that the amount given is only for one furnace, and that a works with ten furnaces would produce ten times as much, or 5,280 tons a week. This it is that forms the huge cinder heaps which are characteristic of the scenery of iron-producing districts. At present no use is made of the slag in this district, except the comparatively small quantity that can be used for ballasting railways, and the heaps are left to weather away slowly under atmospheric influences, or to be buried beneath an accumulation of soil.

In other places, however, especially in Cleveland, the most go-ahead of all iron-producing districts either at home or abroad, many attempts have been made to utilise this waste material. Paving blocks have been, and, indeed, are still made of it. They are hard and durable, and are largely used locally.

Bricks and building blocks have been made by casting the

molten slag in moulds as it flows from the furnace. These, however, have not been very successful; but excellent bricks have been made by first granulating the slag by running it into water, mixing with lime, and pressing into blocks under great pressure. Such bricks have been largely used, and buildings have been erected of them as far from Middlesbrough as London.

Cement is also made from the slag by grinding and mixing it with lime. It is of excellent quality, and closely resembles Portland cement.

Another curious product which is made is slag-wool. If a stream of liquid slag be allowed to run from a spout in front of a powerful blast of air or steam, the slag is broken up into innumerable minute globules, and as each of these is blown away it draws after it a fine tail or thread of slag. The material is blown into chambers of wire gauze, the heavy drops fall out, and the light woolly material is retained. This "wool" is used for many purposes, and forms an excellent non-conducting covering for steam pipes, and is a good packing material, &c. None of these methods of utilising slag are in use in this district, nor have any of them been tried.

Though the ever-accumulating slag heaps are the most conspicuous of the by-products, they are not by any means the most important or the largest in amount, for while for every ton of iron made the resulting slag weighs about 1½ tons, the gas produced weighs as much as 8 tons, or even more.

The effluent gases, even when coke is used as a fuel, are combustible, and are, therefore, of value; but, until recently, they were allowed to escape and burn to waste at the open tops of the furnaces, illuminating the country for miles around, and lighting up the darkness at night with a weird effect. Ironmasters learned not long since that the gases were useful, that they could be burned and used to heat the blast, to raise steam, and for other purposes for which coal had been previously used; and now the gas is always drawn off and thus utilised.

That a blast furnace, into which air is blown in such large quantities, should give off combustible gas may seem strange, but the reason is, that the temperature is very high, and the carbon of the coal or coke used is in such large excess that it can only take up half the oxygen with which it is capable of combining, and thus forms carbon-monoxide, which is combustible, instead of the usual dioxide. In this district the fuel used is not coke, but raw

or uncoked coal, of the variety known as splint coal; and the gases are, therefore, somewhat different in character. At first sight it might seem that the use of coal would be more economical, because of its gaseous combustible constituents, which are expelled in coking, but this is not so. The combustion at the lower part of the furnace raises the products of combustion to a very high temperature, and though these cool very much in their upward passage, they reach the top of the furnace at a temperature of about 600° Fahr. When they come in contact with the coal they are hot enough to expel all the volatile matter, and convert the coal into coke. The volatile matter thus driven out mixes with the other escaping gases, and passes away to form part of the by-products. The furnace thus cokes the coal, and it is only the coke which is usefully burned in the furnace. It is easy to see, therefore, why a much greater weight of fuel is required when coal is burned than when coke is used. Scotch splint coals may be taken as yielding about 60 per cent. of coke.

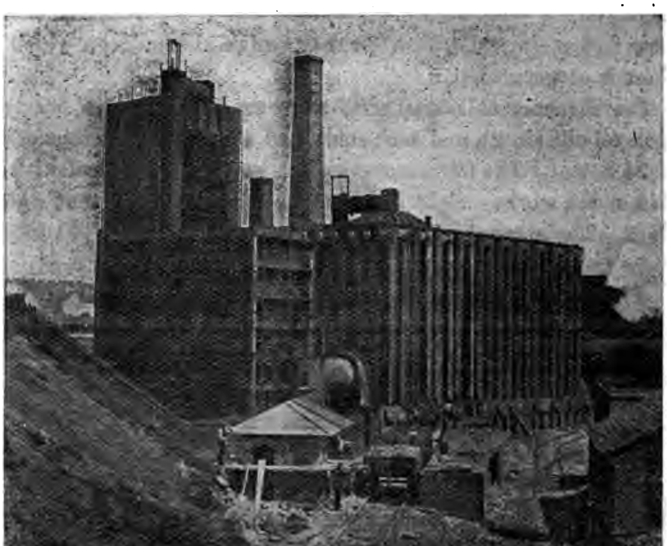
All coals contain a small amount of nitrogen, part of which comes off with the gases in the form of ammonia, and the gases will also carry over a considerable quantity of tarry matter from the distilling coal, which will partly settle in the flues, and partly be carried forward by the gases and burned. In the manufacture of coal gas, the tar and ammonia are recovered and utilised, and, if this can be done when coal is distilled in gas retorts, it should also be possible when it is so treated in the blast furnace; but there is a vast difference between thinking that a thing might be done, or even devising a plan for doing it, and actually putting the plan in operation.

In a gas-works each ton of coal yields about 10,000 cubic feet of gas, while in the blast furnace it yields about 120,000 cubic feet, because, in addition to the gas distilled from the coal, there are also the products of the combustion of the coke and the residual nitrogen of the air. Such a furnace as has been already mentioned, using about 80 tons of coal per day, will yield 9,600,000 cubic feet of gas per day. This enormous quantity will, perhaps, be, to some extent, realised when it is remembered that the whole make of gas in the various gas-works in Glasgow is only 12,400,000 cubic feet per day—far less than is produced by two blast furnaces. It is obvious that such a vast mass of gas will require a plant of very large capacity to deal with it, and the plant will, therefore, necessarily be very costly. What will

be obtained from the gases? The answer to that question is—a certain amount of tar and a small quantity of ammonia, which can be converted into sulphate, the quantity of the latter being about the same per ton of coal as that obtained in the gas-works.

For many reasons the results obtained in a gas-works could not be taken as exactly representing what would be got from the blast furnaces; indeed, the most diverse opinions were expressed as to what would be the value of the by-products when they were obtained, and, therefore, it was not until an actual plant was erected and at work that accurate data could be obtained.

The first attempt to solve the question in a practical way was made, in 1880, by Messrs. Baird & Co., at their Gartsherrie Works. The Bairds have always been to the front in the development of the Scotch iron industry. It may be remembered that they were the first firm to take out a license to use the hot blast, under Neilson's patent, at the same Gartsherrie Works, then just started; and, half a century later, they were the first to make another step in advance, and one that has proved to be of almost equal importance to the Scotch ironmasters. The plant was designed by Messrs. Alexander & M'Cosh, and is, therefore, usually called the Alexander & M'Cosh, though sometimes the Gartsherrie plant.



GENERAL VIEW OF THE ALEXANDER-M'COSH RECOVERY PLANT.

Under the circumstances, it required great courage and confidence in their ability to solve the problem to erect the enormously expensive plant that was necessary to deal with the vast mass of gas, as the plant would have been useless had the process not proved a success.

What had to be done was to separate the tar, amounting to about 20 lbs.; the ammonia, amounting to about 6¼ lbs.; and a large quantity of water, for each ton of coal, and 120,000 cubic feet of gas. For this purpose the gas must be cooled, for as it leaves the furnace it is at a temperature of about 600° Fahr., and till it is below 212° the water will not condense. But cooling is not enough, for even when the tar and water are condensed they will remain suspended in the gas in the form of very fine particles, as a kind of mist, and would, therefore, be carried away by the gases. To avoid this they must be washed out by water, either by "washing" when the gas is made to bubble through water, or by "scrubbing," in which case the gas, ascending a high tower, is made to meet a descending spray of water. In the Alexander & M'Cosh plant cooling and scrubbing are the methods used. (See Plate I., Fig. 1.)

It is not necessary to enter into any elaborate details as to the forms of plant used, all that is necessary is to describe the principles on which they are based; but it is necessary to give some figures in order that one may realise the scale on which the plant is constructed.

The furnaces at Gartsherrie were small (they have nearly all been rebuilt since), and each consumed about 60 to 65 tons of coal in 24 hours. The first recovery plant was erected to deal with one side of the works—eight furnaces, out of the sixteen that were in blast. The amount of gas to be dealt with was about 60,000,000 cubic feet in 24 hours.

The apparatus consists essentially of four parts:—

(1) The atmospheric condenser.
(2) The water condenser.
(3) The scrubbers.
(4) The exhausters.

The gas from the furnaces enters the gas main, and in its passage through this it is somewhat cooled, so that it reaches the atmospheric condenser at a temperature of about 400° Fahr. This condenser, into which the gas first enters, consists of 200 iron tubes about 2 feet 6 inches in diameter and 40 feet high,

DIAGRAMS ILLUSTRATING PROF. SEXTON'S PAPER.

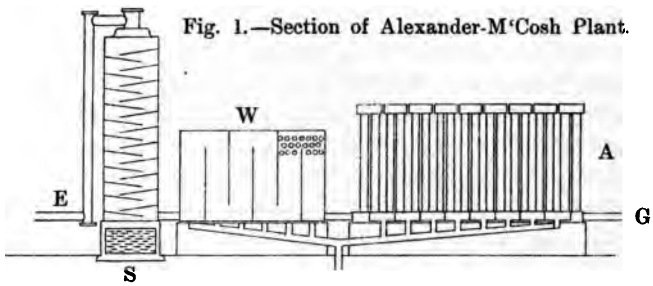


Fig. 1.—Section of Alexander-M'Cosh Plant.

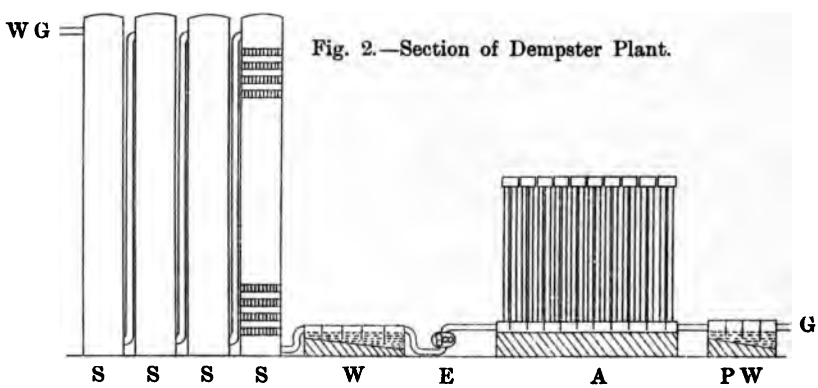


Fig. 2.—Section of Dempster Plant.

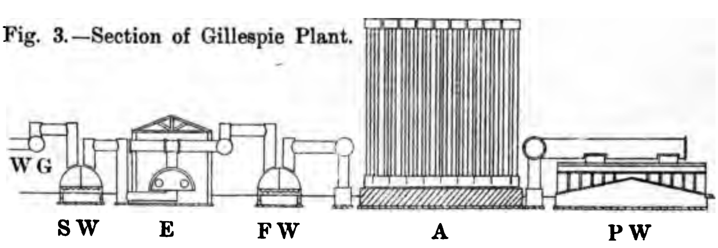


Fig. 3.—Section of Gillespie Plant.

GILMOUR & DEAN, LITHO, GLASGOW.

arranged in twenty rows of ten tubes each. The tubes of one row with those of the adjoining row are alternately connected at the top and bottom so that every particle of gas has to travel through twenty tubes—a course which is 800 feet in length. As these tubes are exposed to the air and can be sprayed with water in hot weather, the cooling is considerable, and the gases leave the condenser at about 120° Fahr., some water and a little tar being deposited in their passage through the tubes.

From the atmospheric condenser the gas passes to the water condenser. This is a chamber made of iron, 45 feet long, 45 feet high, and 18 feet wide, which is divided into a series of compartments (seven in number in this case), alternately connected above and below, so that the gas has to circulate up and down. This chamber is crossed by 2,700 iron pipes about 3½ inches in diameter. These are arranged in a series of horizontal layers, the pipes of each layer being connected by bends outside, so that the water enters at the end where the gas leaves, and leaves at the end at which the gas enters, crossing and recrossing many times on its way. By contact with these tubes the gas is quickly cooled to 60° Fahr., and deposits more water and a little tar, and then passes to the scrubber.

The scrubber is a tall iron tower, 80 feet in height, and 25 feet square, crossed by a number of perforated sloping shelves, so as to break up the ascending current of gas, and bring it into close contact with the water, which descends in the form of fine rain, and thus washes the gas thoroughly, carrying down the tar and dissolving the ammonia. The water which reaches the bottom of the tower, if only used once, would contain too little ammonia for subsequent treatment; and, at the same time, if the escaping gas were not washed with fresh water, ammonia might be carried away. To overcome this difficulty in the first plant two scrubbers were used, the gases being carried from the top of the first to the bottom of the second by a pipe, and the water, after falling through the second, being pumped up to be used again in the first. In the more recent installations the one scrubber is divided by a horizontal tray. Fresh water is allowed to fall through the upper half, and this is then redistributed through the lower half of the tower.

The resistance offered to the passage of the gas through all this apparatus is so great that the blast pressure in the furnaces would not be sufficient to carry it through, and consequently exhausters

of some kind are used—fans, Root's blowers, or blowing engines, which produce a suction of about 1½ to 2 inches of water, and deliver the gas at about that pressure to the boilers.

This plant proved a success, and since its erection another set has been put up to deal with the other half of the furnaces; and a similar plant has been erected at the Lugar works, but in the last-named case the atmospheric condensers are dispensed with, a large water condenser only being used.

Ironmasters, it need hardly be said, had been watching and waiting, and as soon as the success of the Alexander & M'Cosh plant was assured, others set to work to invent modifications.

The next plant for the purpose was that of Mr. Dempster, of Manchester, which was erected at the works of Messrs. Heath, in North Staffordshire. This was patented in 1884. The gas from the furnaces before entering the atmospheric condensers passes through a primary washer. (Plate I., Fig. 2.) This is a box divided into four compartments by iron plates, which do not reach the bottom, so that each division is separated from the next by a seal of liquid. This washer is filled with tar, and if the crude art be used it is partially dried by the passage of the hot gas. The gas then passes to the atmospheric condensers, which are exactly similar to those already described, and then to the exhausters, by which it is drawn from the furnaces and forced forward. Thence it passes through washers, where it bubbles through water, the streams being broken up by a series of perforated plates, and then to the scrubbers. The scrubbers are four in number, 12 feet or so in diameter, and 100 feet high; and they are filled with thin boards set on edge—about 300 tons of timber being used for the four scrubbers.

Entering the bottom of the first scrubber the gas rises to the top, is carried to the foot of the second by a pipe, into which it passes, then to the third, and so on till it has traversed all the four, when it is passed by the return main to the stoves and boilers. The fresh water is supplied to the top of the fourth scrubber, from the bottom of which it is pumped to the second, and so on, thus travelling in an opposite direction to the gas.

This form of apparatus is less costly than the one previously described, and is at work at Govan, Carnbroe, Calder, Glengarnock, and other works in the district. It will be seen that in this plant washing is used not as a substitute for, but in addition to, scrubbing. The apparatus appears to be somewhat simpler than the

first, but the troublesome and costly scrubbers are still retained. At first sight it would seem as if washing should be more efficacious than scrubbing, and if it be properly conducted it is; but there are very great difficulties in satisfactorily applying it, for the gas passes through the water in bubbles, and it is only the surfaces of these bubbles that actually come in contact with the water. It is evident, therefore, that soluble materials may be carried through a very considerable thickness of water without solution taking place.

The first attempt to apply washing systematically in place of scrubbing to the recovery of by-products from blast-furnace gases was that of Mr. Andrew Gillespie, of this city. In his form of plant scrubbers are dispensed with. (Plate I., Fig. 3.) The gas from the furnaces is passed through a primary or tar washer, then through an atmospheric condenser, similar to those already described, and then to the washers. These are long iron boxes containing water, and divided into a series of compartments by plates, so that the gas has to bubble through the water. The compartments of the washer are of very large area compared with that of the tubes, so that the flow of gas is much slower, and the edges of the plates under which the gas passes are serrated by a set of very fine teeth, so that not only is the gas current slow, but it is broken up into innumerable very small bubbles, and in this way intimate contact with the water and perfect solution of the soluble constituents are secured. From the washer the gas passes to the exhauster, then through another washer exactly like the first, and lastly away to be burned.

It will be seen that this form of plant is very much simpler than any of the others, and it is probably cheaper to erect, though I have no reliable data as to absolute cost.

Other methods have been suggested, but as these were intended mainly for the recovery of the ammonia, very little attention being paid to the tar, they have gone out of use, and are not likely to be used again.

The liquors obtained from any form of plant separate according to their specific gravity, the tar being run into one large storage tank and the ammonia liquor into another.

As already mentioned, ordinary splint coals contain about 1·4 per cent. of nitrogen, but when the coal is distilled only about 15 per cent. of this comes off as ammonia, the remainder passing away as free nitrogen, so that the ammonia to be recovered will be

that from about ·21 per cent., or about 4·7 lbs. of nitrogen per ton of coal; but 4·7 lbs. of nitrogen give about 25 lbs. of sulphate of ammonia, and this, therefore, is the maximum that can be recovered under ordinary circumstances. The actual amount will vary with the amount of nitrogen contained in the coal, and perhaps also with the way in which it is combined, and, consequently, it is impossible to be sure of the quantity which ought to be obtained.

The ammonia liquor, which contains the ammonia mainly as dissolved gas, is transferred to suitable boilers, a little lime being added to decompose any ammonium salts that may be present, and the evolved gas is passed into sulphuric acid, the solution evaporated, and the crystals separated and dried, ready for sale. The sulphate obtained amounts to about 23 lbs. per ton of coal, rising occasionally to 25, but more than 23 lbs. cannot be counted on with ordinary Scotch coals. This amount seems small, but with a furnace consuming 500 tons of coal per week, it amounts to about 5½ tons of sulphate of ammonia per week, and larger furnaces will, of course, yield much more in proportion to the coal consumed.

The green tar obtained varies in quantity, but is, on an average, about 40 gallons to the ton of coal, and of this a large quantity is water. It is forced up from the store tank into boilers, where it is heated and the water is expelled, about 16 gallons of anhydrous or boiled tar being obtained from the 40 gallons of crude tar. Subsequently the boiled tar is quickly heated in a still, when oils distil over, and a residue of pitch is left. These oils are usually separated into two fractions:—

(1) Lucigen oil, which has a sp. gr. of about ·970, and is mainly used for burning in "lucigen" or other blast lamps.

(2) Creosote oil, which has a sp. gr. of about ·989. It contains phenols, and is used as a disinfectant, and for other purposes, very largely as a preservative for timber.

When this creosote oil is treated with alkalies and then with blast-furnace gas, it yields a nearly colourless liquid, which, however, darkens on exposure to light. It has been called "neosote." This is a powerful disinfectant, quite equal, according to Mr. A. H. Allen, to ordinary carbolic acid, while it has the advantage of

being less caustic in the strong condition. It is made up in several ways, and sold as a disinfectant.

The amount of oil obtained by the distillation of the tar varies with the degree to which the distillation is pushed, but it is always advisable to stop while the pitch is so liquid that it will run out of the still. Under these circumstances the yield is about 40 per cent. of the tar.

The pitch is used for various purposes, probably most largely for making briquettes with powdered coal.

The tar is very different from that which is obtained in a gas-works. It must be remembered that the tar does not exist as such in the coal, but is produced by the process of destructive distillation, and consequently the nature of the product will depend on the conditions under which it is produced. The tar from the blast furnace contains little or no benzene, which is the source of aniline, and thence of the coal-tar colours, and it is, therefore, of much less value than coal tar. The reason for the difference is that in the blast furnace the distillation takes place at a very low temperature, for it is brought about at the top of the charge by the hot gases, the temperature of which, as already mentioned, about 800° Fahr.

At first blast-furnace tar was of little value. Manufacturers did not know what to do with it, and hence some ironmasters erected plant for the recovery of the ammonia without reference to the tar, but now that uses have been found for the tar its value is as great as that of the ammonia.

The residual gas, after the removal of the tar—"washed gas," as it is called—is used as a fuel. I am not prepared at this moment to discuss the relative value of washed and unwashed gas as a fuel, but I feel sure that the washing reduces the calorific value of the gas, and therefore its practical efficiency—by how much is not definitely known; but many practical men put it down at as much as 20 per cent. The washing also reduces the luminosity of the flame, therefore also its radiative power, and for some purposes its value. This, however, is of little moment. In an ironworks there is always more gas than is needed for steam-raising and other purposes, and the washed gas has the advantage of being cleaner to use, and it can be used directly in a gas engine, and therefore much more efficiently than under the steam boiler.

In addition to the products already mentioned, there are various accidental or occasional products obtained from blast

furnace gases, the most important of which is potassium cyanide. The reactions by which this compound is formed are quite simple. The ore, limestone, and fuel always contain traces of potassium and sodium carbonates. These are decomposed by the carbon at the high temperature of the furnace, the metals being liberated. The alkali metal combines with carbon and nitrogen, forming cyanide. This, being volatile, passes up with the gas, but condenses before it reaches the top and comes down again with the charge. In this way the quantity increases till, in old furnaces, it may leak out through the masonry. Up to the present no method has been found for recovering cyanides from the blast furnace commercially. Lead, zinc, &c., are also occasionally found in the products of the blast furnaces.

We may now, perhaps, sum up the value of the products obtainable. Taking as a basis the production of one ton of pig-iron, the output will be about—

Pig-iron, one ton, value, say,	£2	5	0
Ammonium sulphate, 34 lbs.,	0	3	4
Pitch, 160 lbs.,	0	1	8½
Oils, 15 gallons,	0	1	10½
	£2	11	11

The value of the by-products is thus shown to be 6s. 11d. per ton of iron, or nearly one-sixth of the value of the iron itself.

The following figures have been published with reference to an installation of the Gillespie plant for four furnaces making hematite pig-iron:—

Coal consumed,	2,000	tons per week.	
Pig-iron produced,	1,400	,, ,,	
Pitch recovered,	100	tons, value	£120
Oil recovered,	20,000	gals., ,,	125
Sulphate of ammonia,	20½	tons, ,,	225
Total by-products,			£470

The wages and other costs of working the plant are put at £30, and the cost of acid at £20 10s., leaving a handsome balance for interest, depreciation, and profit.

It may seem that such a subject as this is hardly suitable for the Philosophical Society, but the very width of the scope, name, and work of the Society renders it possible to discuss such a subject in a somewhat different way from that which would be possible in a more purely technical Society. Further, it is desirable

that the *Proceedings* of this Society should contain some reference to the great advances that are made in science and in technology in this district. The fact that the first plant for the recovery of by-products from blast-furnace gases was erected ten years ago has never been mentioned to the Society, and now that the processes have been sufficiently long in operation to have their value fully recognised seemed a fit time to bring the matter before you. As far as the iron industry of this district is concerned, the introduction of methods of recovering the by-products has been of importance second only to Neilson's invention of the hot blast. The merit of Messrs. Alexander & M'Cosh, as the pioneers of the recovery processes, has hardly been sufficiently recognised in this matter. It was not with them that the idea originated, but they were the first to give it concrete shape, and to risk a large sum of money in putting it to a practical test. That their plant has been improved upon is not to be wondered at, for others following had their experience to guide them, and the fact that improvements have since been made does not in any way detract from the credit which is due to those gentlemen as the founders of what has become practically a new industry, and has added largely to the wealth of the district, even if it has not—as some assert—been the means of saving the Scotch iron industry from extinction.

REFERENCES TO PLATE I.

Fig. 1.—A.	Atmospheric condenser.
W.	Water condenser (only a few of the cross tubes shown).
S.	Scrubber.
G.	Gas main from furnace.
E.	Main to exhaust.
Fig. 2.—P W.	Primary or tar washer.
A.	Atmospheric condenser.
E.	Exhaust.
W.	Washer.
S S S S.	Scrubbers (wood-piling partially shown).
G.	Gas main from furnaces.
W G.	Washed gas to stoves, &c.
Fig. 3.—P W.	Primary washers.
A.	Atmospheric condenser.
F W.	First washer.
E.	Exhaust.
S W.	Second washer.
W G.	Washed gas to stoves, &c.

X.—*Glasgow Cathedral: a Contribution to the History of the Structure.* By T. L. WATSON, F.R.I.B.A.

[President's Opening Address, delivered to the Architectural Section, 18th November, 1895.]

[WITH PLATES.]

THE Cathedral Church of Saint Mungo may fairly claim to be the most important, as well as the most interesting, building in Scotland. Although inferior in size and elaboration of ornament to most of the English and Continental cathedrals, the vigour and beauty of its eastern arm or choir have scarcely been surpassed, while the crypt or lower church is among the most original and delightful works of the middle ages. In architectural and antiquarian interest few buildings will compare with our Cathedral, and it offers this attraction to the archæologist and architect that, but for a few stray allusions, its history is not recorded in manuscripts and charters, but must be read in the building itself. With the large majority of mediæval buildings it is a comparatively easy task to determine the dates of the several parts. Except under great constraint, the builders always worked in the style of the moment, and this style is so clearly defined, and its development follows so regular a course, that we can usually ascribe each building, and each part of a building, to its particular date without hesitation and without chance of serious error; but in Glasgow Cathedral we find different periods curiously involved with one another. At certain points the work has been interrupted or delayed, to be resumed and completed at a later period; and it requires more than a superficial glance to determine which part belongs to the earlier and which to the later work. My purpose is to call your attention to a remarkable instance of this in the vaulting

of the crypt or lower church, which has hitherto been regarded as belonging, in the main, both in design and execution, to one period. I shall, however, show that it really belongs to several periods, separated by considerable intervals of time; that the original design was carried out only so far as the aisles; that when the middle part of the church came to be vaulted, this plan was abandoned, and a new design of much greater beauty and richness substituted; and that this was so ingeniously adapted to the older work that the change of design has hitherto escaped observation.

I must first recall to your attention one or two points in the history of the building. The site of Glasgow Cathedral has been consecrated to religion from a very early time, and it is believed that the successive buildings which have occupied it were erected over the grave of St. Kentigern or Mungo, who died in the beginning of the seventh century. Five hundred years later, in the twelfth century, we read of a building having been erected by Bishop Achaius. In 1176 this structure met with what may be called the common fate of the churches of the twelfth century —it was destroyed by fire. It is interesting to note that the desire for stone vaulting in the twelfth century was largely due to the prevalence of such disasters, and that in turn this necessity or desire became one of the leading generative principles which resulted in the style of architecture which we term Gothic. The development of groined vaulting is the development of pointed architecture in a much greater degree than any other constructive motive.

The next church was begun by Bishop Jocelyn, immediately after the fire. It was dedicated in 1190 and again in 1197. In 1198 Jocelyn died. How far the building had been carried towards completion during his lifetime we do not know, and how much, if any, work of this period remains to our day may be subject for discussion. For some years after Jocelyn's death we have no record of building. It may be noted, however, that the charter that had been granted to Jocelyn in 1189, giving him the right to hold a fair as a means of raising money for the building, was confirmed or renewed to Bishop Walter. As we shall see, there is a large amount of work existing which is clearly earlier than Bondington's time, while it is almost certainly later than Jocelyn's. This must, I think, be ascribed to Bishop Walter's period—that is to say, to the second and third decades of the thirteenth century. Walter was succeeded by Bondington, the

great builder of the Cathedral, or, rather, of the eastern half of it. His period was 1233-1253, a brief twenty years; but in that time the lower church and choir, as we know them, were carried a long way towards completion. Contributions were ordered to be taken throughout the kingdom for the purpose of the building, from 1242 till 1249, and we may conclude that that was a period of great activity. Coming to 1277 we find that in that year the chapter purchased the privilege of cutting timber at Luss for building the steeple and treasury, and it may be inferred that the main structure was then nearly complete. In 1286, Alexander III. died, and with the close of his reign there ended a period which has been called "The Golden Age of Scottish History." Peace had been maintained with England for nearly a hundred years, and during this time great progress had been made with agriculture, trade, and social improvement. It is of some importance to note this period and its close in 1286. Its earlier years had seen the church of Jocelyn and Walter in progress; its middle period had seen the new and enlarged choir of Bondington projected and built; and its closing years found the work still unfinished. The death of Alexander was followed by a regency, by the contest for the crown, by the struggle for independence, and by successive wars with England. From 1286 the history of the Cathedral consists mainly of the completion of certain portions that had been left unfinished, and minor additions to the structure, both external and internal. There was a proverb which said of any protracted labour that it was "like Saint Mungo's work, which will never be finished." In the intervals of peace operations were carried on from time to time, but during a great part of this period, if anything was done, the workers must have almost realised the conditions of the building of the walls of Jerusalem, when "Everyone with one of his hands wrought in the work, and with the other hand held a weapon."

I do not attempt to recapitulate the historical references to the building of the Cathedral, meagre and fragmentary as these are. As I have said, the history of the structure must be read in the building itself, and it is a page of this history that we must now endeavour to spell out. I ask your attention first to the vaulting ribs of the lower church. I have drawn the sections of these ribs (Plate II., Fig. 1), and you will see that they arrange themselves in groups, which are shown under different letters. The first group in

of some kind are used—fans, Root's blowers, or blowing engines, which produce a suction of about $1\frac{1}{2}$ to 2 inches of water, and deliver the gas at about that pressure to the boilers.

This plant proved a success, and since its erection another set has been put up to deal with the other half of the furnaces; and a similar plant has been erected at the Lugar works, but in the last-named case the atmospheric condensers are dispensed with, a large water condenser only being used.

Ironmasters, it need hardly be said, had been watching and waiting, and as soon as the success of the Alexander & M'Cosh plant was assured, others set to work to invent modifications.

The next plant for the purpose was that of Mr. Dempster, of Manchester, which was erected at the works of Messrs. Heath, in North Staffordshire. This was patented in 1884. The gas from the furnaces before entering the atmospheric condensers passes through a primary washer. (Plate I., Fig. 2.) This is a box divided into four compartments by iron plates, which do not reach the bottom, so that each division is separated from the next by a seal of liquid. This washer is filled with tar, and if the crude art be used it is partially dried by the passage of the hot gas. The gas then passes to the atmospheric condensers, which are exactly similar to those already described, and then to the exhausters, by which it is drawn from the furnaces and forced forward. Thence it passes through washers, where it bubbles through water, the streams being broken up by a series of perforated plates, and then to the scrubbers. The scrubbers are four in number, 12 feet or so in diameter, and 100 feet high; and they are filled with thin boards set on edge—about 300 tons of timber being used for the four scrubbers.

Entering the bottom of the first scrubber the gas rises to the top, is carried to the foot of the second by a pipe, into which it passes, then to the third, and so on till it has traversed all the four, when it is passed by the return main to the stoves and boilers. The fresh water is supplied to the top of the fourth scrubber, from the bottom of which it is pumped to the second, and so on, thus travelling in an opposite direction to the gas.

This form of apparatus is less costly than the one previously described, and is at work at Govan, Carnbroe, Calder, Glengarnock, and other works in the district. It will be seen that in this plant washing is used not as a substitute for, but in addition to, scrubbing. The apparatus appears to be somewhat simpler than the

first, but the troublesome and costly scrubbers are still retained. At first sight it would seem as if washing should be more efficacious than scrubbing, and if it be properly conducted it is; but there are very great difficulties in satisfactorily applying it, for the gas passes through the water in bubbles, and it is only the surfaces of these bubbles that actually come in contact with the water. It is evident, therefore, that soluble materials may be carried through a very considerable thickness of water without solution taking place.

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The liquors obtained from any form of plant separate according to their specific gravity, the tar being run into one large storage tank and the ammonia liquor into another.

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that from about ·21 per cent., or about 4·7 lbs. of nitrogen per ton of coal; but 4·7 lbs. of nitrogen give about 25 lbs. of sulphate of ammonia, and this, therefore, is the maximum that can be recovered under ordinary circumstances. The actual amount will vary with the amount of nitrogen contained in the coal, and perhaps also with the way in which it is combined, and, consequently, it is impossible to be sure of the quantity which ought to be obtained.

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In addition to the products already mentioned, there are various accidental or occasional products obtained from blast

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The wages and other costs of working the plant are put at £30, and the cost of acid at £20 10s., leaving a handsome balance for interest, depreciation, and profit.

It may seem that such a subject as this is hardly suitable for the Philosophical Society, but the very width of the scope, name, and work of the Society renders it possible to discuss such a subject in a somewhat different way from that which would be possible in a more purely technical Society. Further, it is desirable

that the *Proceedings* of this Society should contain some reference to the great advances that are made in science and in technology in this district. The fact that the first plant for the recovery of by-products from blast-furnace gases was erected ten years ago has never been mentioned to the Society, and now that the processes have been sufficiently long in operation to have their value fully recognised seemed a fit time to bring the matter before you. As far as the iron industry of this district is concerned, the introduction of methods of recovering the by-products has been of importance second only to Neilson's invention of the hot blast. The merit of Messrs. Alexander & M'Cosh, as the pioneers of the recovery processes, has hardly been sufficiently recognised in this matter. It was not with them that the idea originated, but they were the first to give it concrete shape, and to risk a large sum of money in putting it to a practical test. That their plant has been improved upon is not to be wondered at, for others following had their experience to guide them, and the fact that improvements have since been made does not in any way detract from the credit which is due to those gentlemen as the founders of what has become practically a new industry, and has added largely to the wealth of the district, even if it has not—as some assert—been the means of saving the Scotch iron industry from extinction.

REFERENCES TO PLATE I.

Fig. 1.—	A.	Atmospheric condenser.
	W.	Water condenser (only a few of the cross tubes shown).
	S.	Scrubber.
	G.	Gas main from furnace.
	E.	Main to exhaust.
Fig. 2.—	P W.	Primary or tar washer.
	A.	Atmospheric condenser.
	E.	Exhaust.
	W.	Washer.
	S S S S.	Scrubbers (wood-piling partially shown).
	G.	Gas main from furnaces.
	W G.	Washed gas to stoves, &c.
Fig. 3.—	P W.	Primary washers.
	A.	Atmospheric condenser.
	F W.	First washer.
	E.	Exhaust.
	S W.	Second washer.
	W G.	Washed gas to stoves, &c.

X.—*Glasgow Cathedral: a Contribution to the History of the Structure.* By T. L. WATSON, F.R.I.B.A.

[President's Opening Address, delivered to the Architectural Section, 18th November, 1895.]

[WITH PLATES.]

THE Cathedral Church of Saint Mungo may fairly claim to be the most important, as well as the most interesting, building in Scotland. Although inferior in size and elaboration of ornament to most of the English and Continental cathedrals, the vigour and beauty of its eastern arm or choir have scarcely been surpassed, while the crypt or lower church is among the most original and delightful works of the middle ages. In architectural and antiquarian interest few buildings will compare with our Cathedral, and it offers this attraction to the archæologist and architect that, but for a few stray allusions, its history is not recorded in manuscripts and charters, but must be read in the building itself. With the large majority of mediæval buildings it is a comparatively easy task to determine the dates of the several parts. Except under great constraint, the builders always worked in the style of the moment, and this style is so clearly defined, and its development follows so regular a course, that we can usually ascribe each building, and each part of a building, to its particular date without hesitation and without chance of serious error; but in Glasgow Cathedral we find different periods curiously involved with one another. At certain points the work has been interrupted or delayed, to be resumed and completed at a later period; and it requires more than a superficial glance to determine which part belongs to the earlier and which to the later work. My purpose is to call your attention to a remarkable instance of this in the vaulting

of the crypt or lower church, which has hitherto been regarded as belonging, in the main, both in design and execution, to one period. I shall, however, show that it really belongs to several periods, separated by considerable intervals of time; that the original design was carried out only so far as the aisles; that when the middle part of the church came to be vaulted, this plan was abandoned, and a new design of much greater beauty and richness substituted; and that this was so ingeniously adapted to the older work that the change of design has hitherto escaped observation.

I must first recall to your attention one or two points in the history of the building. The site of Glasgow Cathedral has been consecrated to religion from a very early time, and it is believed that the successive buildings which have occupied it were erected over the grave of St. Kentigern or Mungo, who died in the beginning of the seventh century. Five hundred years later, in the twelfth century, we read of a building having been erected by Bishop Achaius. In 1176 this structure met with what may be called the common fate of the churches of the twelfth century —it was destroyed by fire. It is interesting to note that the desire for stone vaulting in the twelfth century was largely due to the prevalence of such disasters, and that in turn this necessity or desire became one of the leading generative principles which resulted in the style of architecture which we term Gothic. The development of groined vaulting is the development of pointed architecture in a much greater degree than any other constructive motive.

The next church was begun by Bishop Jocelyn, immediately after the fire. It was dedicated in 1190 and again in 1197. In 1198 Jocelyn died. How far the building had been carried towards completion during his lifetime we do not know, and how much, if any, work of this period remains to our day may be subject for discussion. For some years after Jocelyn's death we have no record of building. It may be noted, however, that the charter that had been granted to Jocelyn in 1189, giving him the right to hold a fair as a means of raising money for the building, was confirmed or renewed to Bishop Walter. As we shall see, there is a large amount of work existing which is clearly earlier than Bondington's time, while it is almost certainly later than Jocelyn's. This must, I think, be ascribed to Bishop Walter's period—that is to say, to the second and third decades of the thirteenth century. Walter was succeeded by Bondington, the

great builder of the Cathedral, or, rather, of the eastern half of it. His period was 1233-1253, a brief twenty years; but in that time the lower church and choir, as we know them, were carried a long way towards completion. Contributions were ordered to be taken throughout the kingdom for the purpose of the building, from 1242 till 1249, and we may conclude that that was a period of great activity. Coming to 1277 we find that in that year the chapter purchased the privilege of cutting timber at Luss for building the steeple and treasury, and it may be inferred that the main structure was then nearly complete. In 1286, Alexander III. died, and with the close of his reign there ended a period which has been called "The Golden Age of Scottish History." Peace had been maintained with England for nearly a hundred years, and during this time great progress had been made with agriculture, trade, and social improvement. It is of some importance to note this period and its close in 1286. Its earlier years had seen the church of Jocelyn and Walter in progress; its middle period had seen the new and enlarged choir of Bondington projected and built; and its closing years found the work still unfinished. The death of Alexander was followed by a regency, by the contest for the crown, by the struggle for independence, and by successive wars with England. From 1286 the history of the Cathedral consists mainly of the completion of certain portions that had been left unfinished, and minor additions to the structure, both external and internal. There was a proverb which said of any protracted labour that it was "like Saint Mungo's work, which will never be finished." In the intervals of peace operations were carried on from time to time, but during a great part of this period, if anything was done, the workers must have almost realised the conditions of the building of the walls of Jerusalem, when "Everyone with one of his hands wrought in the work, and with the other hand held a weapon."

I do not attempt to recapitulate the historical references to the building of the Cathedral, meagre and fragmentary as these are. As I have said, the history of the structure must be read in the building itself, and it is a page of this history that we must now endeavour to spell out. I ask your attention first to the vaulting ribs of the lower church. I have drawn the sections of these ribs (Plate II., Fig. 1), and you will see that they arrange themselves in groups, which are shown under different letters. The first group in

Fig. V. No. II.

Fig. VI. No. IV.

point of time is the one which I have called A. This is a moulding which belongs to the end of the twelfth century and the beginning of the thirteenth. The mouldings of the second group, marked B, are obviously later than the A mouldings. They belong to the first half of the thirteenth century, probably about 1240. The third and fourth groups, marked C and D, are later in the same century. C is a characteristic moulding of the middle of the thirteenth century, and D is a little later. So far, I think, we are on sure ground. When we come to the mouldings marked E, there may be room for difference of opinion. They are certainly much later than any of the others: I should judge them to be about the middle of the fifteenth century; but the exact date is not material to us at present. If we cannot fix the dates of these mouldings precisely, we can determine most of them within a few years, and we know with certainty the order in which they were used. The development of the mouldings is part of the development of the style, and I am not going to enter upon so large a subject. There is one incident, however, in this development that may be referred to, as it helps to illustrate a point that has to be mentioned later. The sections of the earliest mouldings shown, those marked A, finish on the under side with a sharp point, which in the rib, of course, becomes a sharp edge. In the work of building that is not altogether the most convenient form. The separate stones of each rib or arch have to be supported on wooden centering till the arch is completed, and this moulding, A, would rest very awkwardly on the flat surface of the ordinary and simple form of centering. It would require a special form of double centering to support the stones, or else the stones would have to be blocked up on each side to keep them in their places. The B mouldings would not be quite so troublesome, but, as they are rounded underneath, they would still require some attention to keep them from rolling over to one side. In all the later mouldings this difficulty is avoided by making the stones of a section that would rest quite steadily on the wooden centering.

We come now to the plan of the lower church (Fig. 2), which we have to consider in the light of the mouldings that we have been looking at. The tomb of St. Kentigern is believed to be in the middle of the crypt, and there is no doubt that each successive building was erected over that spot, which was hallowed by long association with religious service. In Jocelyn's time the churches had short chancels, and the tomb of the saint would then be in

the east end, in a small crypt under the high altar. Early in the thirteenth century the enlarged choir was projected either by Walter or by Bondington. The old chancel or choir had then to be pulled down, and a new and much larger one erected in its stead. But there were two conditions which had to be observed—the daily services of the church had to be maintained, and the relics of the saint had to be reverently guarded. You understand, of course, that we have no historical evidence of what took place in the Cathedral at this time; but we know what took place elsewhere at the same period and under the same conditions. We may at least construct an hypothesis in order to explain something in the building which cannot otherwise be accounted for. We may assume that what took place in other churches in which the bodies of saints were preserved may have taken place here also. We may even, I think, go farther, and say that something like what I am about to describe *must* have taken place.

When it was decided to take down the then existing choir and build a new and larger one, it was necessary that a place should first be prepared to receive the bones of St. Kentigern until the new shrine should be built. This place must be as near as possible to their former, which was to be also their future, resting-place. The plan of the new choir was drawn out, and it was determined to reserve a small compartment of the under church for the reception of the saint. The part so reserved, according to my hypothesis, was at the west end of the south aisle. Here, at all events, we find portions of two bays considerably older than any other part of the choir. The vaulting ribs are those called A 1 and A 2 (Fig. 1), the former being the transverse rib and the latter the diagonal one. It is unmistakably the oldest part of the vaulting. This compartment having been finished, we may suppose that the remains of St. Kentigern were removed to it, and that, for the time being, it was enclosed with walls, and formed a small chapel approached from the nave by a stair. The old choir was then demolished, and the builders were set to work to rear the great new choir of their Cathedral. The original design for the crypt, however, was different in one respect from that which has been carried out. The central part was designed with plain vaulting, supported by parallel rows of columns, as I have shown it on my plan (Fig. 3).

That this was so I shall demonstrate beyond the possibility of doubt. In the meantime, for a few moments, I ask you to take

it on trust. Our builders proceeded at once with the walls and the outer row of pillars, and they completed the aisle vaulting as we see it to-day on the north, south, and east sides of the crypt. They did not complete the vaulting of the eastern chapels, except the one to the north, which forms the entrance to the chapter house. In the middle of the crypt they built neither pillars nor vaulting, but left the space open and unobstructed. In all the vaulting that was done at this time, the B ribs were used. In the north and south aisles, B 1 is the transverse rib and B 2 the diagonal. In the eastern aisle heavy arches of the same type of moulding take the place of transverse ribs, in order to reinforce the pillars that carry the great eastern gable, and the diagonal ribs are of the B 1 moulding. While building the pillars and vaulting of the aisles, it was necessary, at the same time, to form the springing of the vaulting of the middle part of the crypt, and this was done as shown by dotted lines on the section (Fig. 4). The mouldings on these were, of course, the B mouldings.

Having completed the aisle vaulting, the builders proceeded to carry up the walls and pillars of the choir above the level of the crypt, and, to enable them to do this with facility, it was necessary that the middle part of the crypt vaulting should be left unfinished. The clerestory walls of the choir were to be carried up to a height of 85 ft. above the ground, and the eastern gable to a height of 110 ft. We know that the mediæval builder always studied to work with the smallest possible amount of scaffolding. To have raised his stones outside the aisle walls, and then to have carried them to their places on the clerestory walls, would have required an immense quantity of heavy scaffolding, and it would, at the same time, have greatly increased his labour. When he saw that, by delaying the vaulting in the middle part of the crypt, he could bring every stone directly under the part of the wall on which it was to be built, he at once decided to do so. I think we may reasonably surmise that the material, as it was prepared, or the greater part of it, was brought in by the two middle east windows, and that, to admit of this being done, the mullion or pier in each of these windows was left out until the clerestory walls were finished. That is the most direct and natural way of carrying on the work, and there is an interesting confirmation of my conjecture that it was the method followed in the fact that these two windows have been specially designed to serve this useful purpose. Unlike all the other windows of the crypt, these two coupled windows

are enclosed each under a single arch, so that the middle part could be filled in without trouble at a subsequent time. By this means a wider and more direct entrance to the building was obtained than could have been found otherwise.

Having left our builders proceeding with the walls and pillars of the choir, we find, on returning to them, that they have reached the level of the vaulting of the north aisle of the Cathedral a little sooner than that of the south aisle. In the north aisle and over the eastern chapels of the upper church, one of the C mouldings is used, but it is used in conjunction with one of the B mouldings. In the south and east aisles nothing but the C moulding is used, from which we conclude that these last are later than the others. The choir aisle vaulting having been completed, the builders went on with the clerestory walls and the great east gable. When these were finished, the aisles received their wooden coverings over the vaulting, and the middle part of the choir received its wooden roof. The building was now closed against rain, but it was still far from being complete. The middle part of the vaulting of the lower church had still to be constructed. This vaulting is the chief glory and distinction of our Cathedral, and to it, if I have not wearied you, I shall devote the few minutes that have still to be occupied.

Was it the same architect as had originally designed the plain vaulting and parallel rows of pillars (Fig. 3) who now returned to it to complete his work, or was it a new man? I am afraid that question cannot be answered. Whoever he was, he was dissatisfied with the earlier and simple design of the vaulting. The shrine of St. Kentigern, he thought, deserved something more original and striking. The art of vaulting with arched ribs had been in its infancy when this work was designed; now, when it came to be constructed, it was in its maturity. Was he to go back and slavishly carry out the early and common-place design? He was not content to follow such a course. Fortunately for us, he decided upon a new design, in spite of the fact that he was hampered by the old springers on all the outer pillars, which, having been designed to suit the first scheme of vaulting, lent themselves badly enough to the new plan. He was a man of genius and resource, and he set himself to overcome the difficulties that lay in his way.

The narrow western aisle of the crypt had been completed during the construction of the upper part of the walls. At all

events, we find here the B and C mouldings mingled, and draw our conclusion from that fact. Having laid out his new plan of the central compartment (Fig. 2), our architect proceeded to carry it into execution. The tomb of the saint is surrounded by four pillars in the same position as four of the pillars in the old design; but, as these pillars are not part of a long range as before, they acquire a greatly increased importance, and, with their vaulting, form a kind of canopy over the tomb. Two more pillars are erected three bays to the east. That left two large squares, with three arches on each side of each square. In the middle of each of these squares our architect erected a pillar. Instead of sixteen pillars to carry the floor of the choir he is content with eight only, and, to that extent, he leaves the under church unencumbered and unobstructed. His next step is to throw across four arches in each square from the central pillar to each one of the corners. For these arches he uses the C 1 moulding, and at each of the outer pillars he simply cuts out the old springer and inserts a new stone, with the C 1 moulding wrought on it. That is an easy way of treating the old springers, but it is not a method that can be applied throughout. It would cut away too much of the stone, and tend, in the case of the large alternate pillars, to weaken and undermine the pillars of the choir which they carry. He considers that in giving new springers to his most important ribs he has gone as far as he can go with safety, and that he must follow another course with the others. I shall start at the west end and describe what he has done in each case.

In the respond or pillars, No. I., north and south (Figs. 2 and 3), the diagonal rib on the west side has been already built, and on the other, the east side, it was dealt with as we have just seen. The transverse rib he has treated in the same way. This is not a pillar that carries anything in the choir above, so that there is no difficulty in cutting out the double springers and inserting new ones. At the pillars, No. II., north and south, our architect finds the springing of three vaulting ribs, but in his new plan he only requires two. He therefore cuts off the middle one, but, in order not to weaken the support to the pillar above, and also to avoid leaving a deep hollow between the two diagonal ribs, he does not cut it away entirely. He cuts off the front part of the rib, but he leaves the back. Fig. 5 is a view from a photograph of No. II. pillar, north. He is now left with the two diagonal springers which he is going to use. You will notice, however, that in the new plan

of the vaulting (Fig. 2) the two ribs are required to take a slightly different direction from that which they were originally intended to take (Fig. 3). Here is a little difficulty. How is it to be got over? The new rib, which was made in continuation of the old springer, has been adroitly twisted into its new direction. It is not very marked; the proof of that is that it has hitherto escaped notice, but, when your attention is called to it, you will see that it is unmistakable.

In the pillars, No. III., the same difficulty has been encountered, and on the north side it has been met in exactly the same way. On the south side a slight difference is observable. The rib springing towards the east has to be diverted or twisted to some extent, and our designer decides that his best plan will be to alter the moulding slightly on the old springer. You will see at C 3 (Fig. 1) what he has done. The dotted line shows the outline of the old moulding, which is the one called B 2. By cutting it down a little he has altered it to the new moulding, C 3. The alteration is very slight, but advantage is taken of it to obtain a flat fillet on the under side, presumably for the greater convenience which this offers in poising the stones on the centering. Coming now to the pillars, No. IV., we have first, on the west side, one of the new springers already referred to. In the middle or transverse rib we find another case of alteration of the moulding. This was originally the B 1 moulding, and it is now cut down and altered to the D 2 moulding (Fig. 1). In the case of the north pillar the diagonal rib springing towards the east is kept with the original moulding, but in the corresponding pillar on the south side it has been changed, as in the case of the previous south pillar, from B 2 to C 3. This pillar is shown from a photograph in Fig. 6 (middle of photograph). In the next pillars, No. V., exactly the same course has been followed as with No. IV. south. Nos. VI. and VII. pillars have been treated as before, the middle rib having been cut away, the old moulding being kept in the diagonal ribs, which again have been somewhat twisted. In No. VIII. pillar, north and south, we have again a new springer, a converted springer, and an old springer slightly twisted, and in No. IX., north and south, we have a converted moulding in the middle between two unconverted ones. In the three pillars at the east end there are none but old mouldings. The transverse rib from the middle one of these pillars is of the section shown in B 3. It is the only place where this moulding

occurs. The other mouldings will be understood from the plans (Figs. 2 and 3).

We have now completed the vaulting of the lower church all but the three eastern chapels. These were left unfinished for a time, and I would suggest that this was done with the object of throwing as much light as possible from the upper windows into the middle part of the crypt while the operations at that part were in progress. It was quite natural, and indeed necessary, that this part of the vaulting should have been left to the last, but we cannot explain the fact that it was left over for some two hundred years, as we may judge from the mouldings, which are the late mouldings marked E on Fig. 1. These are probably of the fifteenth century. The close of Alexander III.'s reign, in 1286, must have found this part of the work unfinished, and we can only suppose that an opportunity of completing it was not found for something like two hundred years, that the bishops were, as we know was the case with one of them, more intent upon fighting than on building.

There is one rather interesting point in connection with this much belated part of the vaulting. The north chapel, as we have seen, was vaulted along with the aisles at the period of the B mouldings, about 1240. When the chapels of the choir above were reached, a rib was put in between the diagonal ribs on the east side. Now, in the fifteenth century, when the south-eastern chapel of the under church was vaulted, a similar rib was put in on the east side, coming down on the capital between the two windows. The architect was pleased with the effect, and decided that he would introduce the same feature into the vaulting of the north-east chapel also. Here, accordingly, we find the late moulding inserted in the middle of the early vaulting and between the early diagonal ribs. Not content with this, he did the same at each end of the east aisle. Walking round the aisles, we accordingly have this feature at the end of each of the four vistas —that is to say, at the east end of the north and south aisles, and at the north and south ends of the east aisle.

I had intended to refer briefly to the vaulting and some other features of the other parts of the Cathedral on which these inquiries throw some light, but I feel that I have engaged your attention too long already. The middle crypt of Glasgow Cathedral is one of the most beautiful and original pieces of vaulting in existence. There is no absolutely new principle contained

in it, as Sir Gilbert Scott has told us, but there is a combination of fertility and felicity of invention with skill in execution. One cannot sufficiently admire the beautiful contrast that it offers to the more formal and regular vaulting of the aisles, while its harmony with this vaulting is such that no one has hitherto suspected that it was not part of the original design. There is no parallel to this piece of vaulting to be found, and I do not know of any case in which a new design has been so ingeniously and so successfully engrafted upon an old one.

XI.—*Visit to Lake Titicaca, Peru.* By Mr. JOHN WILSON, Glasgow.

[Abstract of Paper read before the Society, 4th March, 1896.]

THIS paper gave an account of the transmission of a steamer of 550 tons (built at Leven Shipyard, Dumbarton) from the coast of Peru, up the Andes, 13,000 feet, to Lake Titicaca—the highest navigable lake in the world,—and its reconstruction there. The steamer was built for the Peruvian Corporation (Limited), London, under the superintendence of the author, with the view of increasing the commercial and passenger traffic between Peru and Bolivia. After being temporarily erected at Dumbarton, the steamer was shipped, in pieces, by the *Gulf of Florida*, to Port Mollendo, the seaport town for the lake. The parts were lightered ashore through a very heavy surf, and loaded on freight cars for transportation to Titicaca, *via* the Southern Railroad, over a distance of 325 miles. About twenty cars were required for the conveyance of the whole of the material. This railroad is a narrow-gauge one and single line, and hence the placing of the parts of the vessel and her machinery and boilers upon the cars had to be done with the utmost care, the more especially as they had to pass through a short tunnel of small sectional area. This tunnel is situated between Arequipa (or the "half-way house") and the lake. The boilers, two in number, weighed each 15 tons, and were riveted up complete before leaving the Clyde. They had to be raised from the lighters by means of a pair of shearlegs specially erected for the purpose. The loaded trains each took about eight hours from Mollendo to Arequipa, and twelve hours for the rest of the journey.

All the work hitherto spoken of was under the closest surveillance of the author, whose principal anxiety in connection therewith had to do with the removal of the boilers from the vessel's hold into the lighters, and their transmission ashore through the surf, which is certainly the heaviest over all the west coast of South America, and the dread of all sea captains trading to and from Mollendo.

He also superintended the reconstruction of the steamer on the shores of the lake, in the Bay of Puno, which is its principal port, and steam trials across the lake and back. The ground on which the steamer was re-erected was a portion of a potato patch, belonging, for the time being, to an old Quichua Indian. There being practically no rise and fall in the lake, launching preparations were of a different nature from that on the Clyde or other place where there is ebb and flow. The ways were constructed of bridge timbers, loaned for the purpose from the owners of the railway, the country at this height—13,000 feet—being entirely destitute of forest growth. The work of re-erection was done principally by native labour, procured in most part at Arequipa, where there is a locomotive repair shop; and this labour, partly skilled in boiler work, was supplemented by the unskilled labourers of the lake region.

From the laying of the keel until the trial trip of the new steamer—named the *Coya*, which signifies lawful Inca princess —a period of twelve months minus two days was required, with the exception of all Sundays, which were days of rest, and the national feast days, which sometimes occurred at the rate of two or three per month. All this time the author had no thoroughly skilled or technical help, except that of one Dumbarton ship carpenter—an engineer being provided by the corporation to take charge of the machinery for a period of six months after completion of trial. Each voyage of the steamer extended over about 100 miles—the lake itself being 120 miles long,—and was accomplished in about 10 hours.

The author stated that he had not sufficiently acclimatised himself at Arequipa by resting for some days there before making his ascent to the summit of the pass, which is at a height of 14,666 feet above the sea level. In consequence of his hurrying away to the end of his journey he suffered to some extent from headache (*sorotché*), due to the breathing of the highly rarified atmosphere at this altitude.

Speaking of the lake itself, he said that it contains several islands, the chief of which are Titicaca and Coati—the former being sacred to the worship of the sun, and the latter to that of the moon,—and on which are found relics of the ancient sun worship of the Peruvians. On its shores there are towns showing evidence of former prosperity, but the present inhabitants are silent, dull, and phlegmatic, lacking alike in intelligence and

enterprise. The Indians around the lake, when sober, are a harmless race. The women are short in stature, with oval faces, but from their precarious mode of life such beauty as they possess is soon lost, and they become shrivelled and shrunken at an early age. They are very industrious, and even while travelling they are always employed spinning cotton or wool with a spindle. Cleanliness is not one of the virtues possessed by either men or women. In the towns the feast days are passed in dancing, drinking, and rioting. Sunday is market day, and the market place presents a picturesque sight. The natives come from the surrounding country with loads of provisions, the llama or Peruvian sheep being the beast of burden, and the produce is spread out in the plaza, sunshades or improvised tents being erected overhead. Here, also, are sold coarse native-made cloth, boots, pottery, &c.

Subsequently the author gave an account of a visit which he paid with a friend to Cuzco, the ancient capital of Peru and royal residence of the Incas. The scenery through which he passed was of the loveliest character, and the country is rich and fertile. Cuzco has many most interesting remains. The temple of the sun is still standing, but the palaces of the Incas and the houses of the ancient nobility are going to ruin. The city was in a state of revolution at the time of his visit, and for three days he was unable to leave his hotel, the proprietor of which was a Scotchman, hailing from Edinburgh, who had been for a number of years a pedlar in the country before he settled down in the ancient capital. Two towns near Cuzco were also visited by the author, who said of the common people of the country that they were wretchedly poor and knew nothing of the blessings of civilisation. Speaking generally of Peru, especially of the interior, he described it as a grand country, which might in the future see a revival of its ancient prosperity.

After completing his contract duties and taking his trip to the ancient capital of the country, the author returned to Mollendo, and proceeded by steamer north to Callao, thence by rail to Lima, the present capital of Peru, from which city he made a journey to and from Oroya, the present terminus of the Central Railway of Peru,* and returned home *via* Panama.

* See paper on "Exploration of the Amazonian Provinces of Central Peru," by Alexander Ross, F.R.G.S., Vol. XXIV. of *Proceedings*, p. 148.

The *Coya* is a twin-screw steamer of the following dimensions:— Length between perpendiculars, 170 feet; breadth, moulded, 26 feet; depth, moulded, 12 feet; and is fitted up for the accommodation of 45 first-class and from 30 to 40 second-class passengers.

Numerous lime-light views were used in the illustration of the paper, including the steamer under various stages of construction, Inca ruins, natives, and the Inca King.

XII.—*The late Mr. W. P. Buchan, Sanitary Engineer, Glasgow.* By JAMES CHALMERS, I.A., Past-President of the Sanitary and Social Economy Section.

[Read before the Society, 15th April, 1896.]

THE late Mr. W. P. Buchan was born at Fraserburgh (Aberdeenshire), on 7th December, 1836. It was intended that he should study for a clerical or medical career, but his bent was found to be towards mechanics in some department or other. At the age of sixteen he was apprenticed to Messrs. Whyte & Henderson, who carried on business in Sauchiehall Street, Glasgow. This firm was at that time one of the leading firms of plumbers in the city, and had acquired a special reputation by the introduction of hot water supply into tenement dwelling-houses in Bath Street, which was then considered to be a wonderful advance in houses of this class. Young Buchan was spoken of as a "thinking lad," and in those days this was a good qualification. The journeyman plumber and his apprentice had to depend very largely upon their own ideas in much that related to the sanitary arrangements of houses, and especially when sent to discover the defects that they were expected to remedy. Forty years ago workmen were very conservative in some things: as a rule, they were anything but disposed to disclose their methods to their fellow-workers, and certainly not to those in a rival shop.

In 1853, a journeyman plumber named Wallace, in the employment of Mr. Lockhart, was sent to cure a smell in a gentleman's house at Garnkirk, near Glasgow, and, being one of the "thinking" plumbers, he hit upon the idea of cutting a hole on the house side of the trap, and carried a pipe from it to the roof. This was probably the first case in Scotland of what we now call the fresh-air opening of the trap. This improvement was so satisfactory that it became known in the trade that Lockhart's shop was doing this thing, and there is no doubt but that young Buchan would come to hear of it in Whyte & Henderson's, and instantly

grasped its importance from a sanitary point of view. Shortly after this Mr. John Honeyman, architect, Glasgow, now well known as a Fellow of the Royal Institute of British Architects, and an R.S.A., Edinburgh, took out provisional protection for a patent ventilating trap, which he called the "Somerset Trap;" but he did not apply for the full patent.

Mr. Buchan having finished his apprenticeship and improved his knowledge of kindred subjects by attending evening classes, started business on his own account in 1860. He continued to devote his attention to ventilation in addition to house drainage, and, in particular, he appreciated the immense value of a good trap for house drains and sewers. He patented what is now known as "Buchan's Trap," and by lectures and writing upon the subject he soon convinced architects and their clients of its value. He patented what is known as the "Cascade action" in this trap, and so far it differs from the Somerset Trap previously devised by Mr. Honeyman. Irrespective of the relative merits of these two inventions, there is no doubt that the conviction in the public mind that trapping was necessary is mainly due to the advocacy of Mr. Buchan, and to the fact that he carried through his patent and placed it upon the market.

It was in 1871, however, that Mr. Buchan came to the front as a sanitarian. At the request of the proprietors of the *Building News*—when public attention was drawn to the subject by the illness of H.R.H. the Prince of Wales,—he contributed a series of articles on plumbing to that paper, and these, with some additions on house drainage, were afterwards published as No. 191 in "Weale's Series." This was probably the first plumbers' handbook ever published in this country. The book in question has been of great value to the young plumber, and, indeed, to all interested in sanitary matters. It has reached its sixth edition, and Mr. Buchan revised a seventh edition shortly before his death.

After completing his trap and getting it into general use, he made improvements from time to time in almost every department of his work, such as cleaning eyes for longitudinal pipes, improved grease traps and boxes, wash-down closets, patent exhaust ventilators, and anti-down-draught valves. His improved appliances have a high reputation both at home and abroad, and probably no other sanitarian (certainly none in Scotland) has been so frequently consulted by architects and by the public generally

in all that relates to house drainage. One of the most valuable appliances which he claimed to have invented was the smoke-testing machine, but he did not ask the protection of a patent. Somewhat similar, if not the same, machines are now in constant use, and are recognised as being invaluable to the sanitarian. Mr. Buchan's work in this direction alone entitles him to rank as a public benefactor.

A year or two prior to the Plumbers' Registration movement in Scotland, meetings of the master plumbers of Glasgow and Edinburgh took place to consider what test could be adopted to ensure that young plumbers especially were qualified for the position and wages of journeymen. The masters found that since the indenture system had fallen into disuse, lads who had served three or four years at their trade left their employers and posed as journeymen in a new shop. The idea of registration was received with favour—the masters to be the judges,—but, owing mainly to the jealousy which exists between Glasgow and Edinburgh, the negotiations fell through. Mr. Buchan took little or no part in these negotiations, but whenever the matter was gone into by the London master plumbers, and the patronage and funds of the Worshipful Company of Plumbers were found to be available, he went heart and soul into the work. He introduced the Organising Secretary to the master plumbers of Glasgow, and, until his death, was earnest in furthering the success of the movement. He attended the Plumbers' Congress held in London in connection with the Health Exhibition in 1884, and took a very active part in the proceedings.

In 1891 he again appeared as an author with his valuable book on "Ventilation." An examination of this book shows him to have been well read in the current literature and standard works connected with sanitary science, and that all his experiments—particularly those upon the composition of the air in public buildings, and more especially public schools,—had a great fascination for him. In this volume he treats very fully upon mechanical ventilation, and, although this was not one of his departments of business, he undoubtedly had a great admiration for it where the buildings were of large cubic area, and where funds were available to defray the cost. He was, nevertheless, a severe critic of mechanical ventilation, and will certainly be best known as a successful exponent of natural ventilation, and an advocate of what is known as the sectional system of drainage; and, irre-

spective of whether or not he was right in all he taught and laboured for, there is no doubt but that he convinced the public of his eminence as a sanitarian, and thereby fostered the great interest now generally taken in the subject of public health.

Among his studies (outside of sanitary work) one of the earliest was Freemasonry. He was a member of St. John's 3 Bis., the oldest masonic lodge in Glasgow, and, in his opinion, the third oldest in Scotland. On the historical aspect of masonry he was an undoubted authority. Lyon, in his work on "Freemasonry in Scotland," says that he did much to place the history of freemasonry upon an authentic basis. He was an honorary corresponding member of the German Masonic Union. In connection with his studies in this direction he devoted considerable time to reading old charters, particularly those connected with Scotch cathedrals; and upon Glasgow Cathedral he was admitted to be an authority. His researches as an antiquarian led him to suspect the authenticity of some dearly-cherished charters and opinions, and he did not always receive the thanks of those whom he endeavoured to put right upon these matters.

The critical faculty he applied to everything, including the Old and New Testaments; and on religious subjects he was a voluminous contributor to the agnostic and other journals, as well as to the daily press.

Possibly the meetings which had the greatest interest for him were those of the Philosophical Society of Glasgow, of which he was made a life member in 1875. He was early elected a member of Council, was Vice-President, and afterwards President, of the Sanitary and Social Economy Section. Out of this section sprang the Scottish Burial Reform and Cremation Society, Ltd., and he attended and spoke at the first meeting, was always a director, and his remains were cremated at the New Crematorium in Maryhill, on 22nd February last. He was an ardent cremationist, and it is remarkable that he was the first cremated after the formal opening of the buildings, in whose design and erection he took a very keen and intelligent interest.

The other societies in which he took a warm interest were the Royal Scottish Society of Arts, Edinburgh, of which he was made a Fellow in February, 1879; the Society for the Encouragement of Arts, Manufactures, and Commerce, which he joined in February, 1881, and of which he was a Life Member; the Society of Science, Letters, and Art, of London. He was also a Life Member of the

British Association, which he joined in 1885; an Associate of the Sanitary Institute of Great Britain; a Member of the Sanitary Association of Scotland; Associate Member of the Institution of Engineers and Shipbuilders in Scotland; and Life Fellow of the Scottish Society of Literature and Art, Glasgow.

He was also a Member of the following Trades' House Incorporations:—Hammermen, Cordiners, Bonnetmakers, Dyers, and Gardeners, and of the Anderston Weavers' Society. The mention of these societies shows how wide-spread was his interest in everything which fostered and developed all that related to science and art, as well as the lighter walks of literature.

He died on Thursday, 19th February, aged 59 years, and in him science has lost a reverent student, and sanitary science one of its ablest exponents.

THE NEW PHOTOGRAPHY.

XIII.—*On the Röntgen X Rays, or the New Photography.* By Dr. J. T. Bottomley, F.R.S.; the Right Hon. Lord Blythswood; and Dr. John Macintyre, F.R.S.E.

[Read before the Society, 5th February, 1896.]

Three papers on different branches of the subject of the X rays of Professor Röntgen, of Wurzburg, were communicated to the Society at the meeting held as above.

I.—Dr. J. T. Bottomley on the Discoveries of Hertz, Lenard, and Röntgen.

I have been asked to open this joint-communication from Lord Blythswood, Dr. Macintyre, and myself, and to say a few words on the subject of the discharge of electricity through vacuum tubes, and particularly on such parts of the subject as may be considered to have led up to the wonderful discovery by Professor Röntgen, which, within the last few weeks, has taken the scientific world, and even the general public, by storm.

The beautiful luminous phenomena which accompany the passing of an electric discharge through a vessel, which has been almost completely evacuated of air, have long been known; and, indeed, I myself have had the pleasure, on more than one occasion, of calling the attention of the Society to some of them.

When a discharge is passed through air of ordinary density, it generally passes as a spark or as a "brush" discharge, with more or less disturbance of a somewhat violent kind, and in an obviously discontinuous manner. If the points between which the discharge is taking place are within a glass tube, the effect is still the same. But if now the air is withdrawn gradually from the tube by means of one of the modern air pumps, with which we can obtain a very complete vacuum, we observe a very interesting set of phenomena as the process of evacuating the tube goes on. When the pressure

of the air in the tube is reduced to about 1mm. or 0·5mm., the sparking character of the discharge entirely disappears, and the tube is filled with a beautiful glow of light, the colour of which depends on various circumstances—partly on the condition of the vacuum, partly on the nature of the gas which filled the tube originally and of which a residue still remains in the tube, and partly on the kind of glass of which the tube is made.

On carrying the process of pumping the air out of the tube still further, a very remarkable state of matters supervenes, which was discovered by Crookes, and which is the foundation of all the radiometer phenomena with which the name of Crookes is connected. When there is left within the tube not more than, say, one-millionth of the original quantity of air, and when the pressure of the air that is left has been reduced to a corresponding extent, the particles of the residual air become comparatively free to move about without being in incessant mutual contact and collision. They are then shot off from the negative electrode, or cathode as it is called, and they fly with great velocity through considerable distances—several centimetres, perhaps—before they chance to strike other particles, or to hit upon the side of the tube, or on any solid which may be within the tube. Any one particle may, of course, very soon strike something in its flight, but on the average many particles move through long straight paths without encountering an obstacle or meeting another particle. I have had the pleasure of showing some of these phenomena in this room, and only refer to them now because it is necessary to bear them in mind in considering the further developments of this matter which recent investigation has brought to light.

I must now call your attention to the contributions to this subject of the late Professor Hertz, and of his friend and pupil, Dr. Lenard. In a very remarkable paper, published in 1892, Hertz described what he called the "Passage of Cathode Rays through Thin Metallic Layers." He showed that the interposition of a thin layer of gold leaf, for instance, in the path of the cathode rays,* does not stop them. A thin plate of mica acts as a perfect screen to these rays, although the mica is quite transparent to ordinary light, while a thin plate or layer of gold, silver, tin,

* It is difficult to find language to use in this connection, because there exists at present a controversy as to the nature of the cathode discharge into which it would be impossible for me to enter here.

&c., perfectly opaque to ordinary light, permits the cathode rays to pass through with tolerable freedom. The experiments of Hertz were carried on within the vacuum tube, but later, Lenard, at the instance of Hertz, carried out some important further experiments in which the cathode rays were obtained *outside* the tube, and their properties carefully examined. Lenard constructed a tube in which the end opposite to the cathode was closed, not by glass sealing, but by a metallic cap of brass, or other suitable metal; and in this cap a minute hole was cut. The hole was covered with a small piece of excessively thin aluminium foil, which would have been far too thin and weak to form the cap, but which, when used simply as a cover for the minute hole in the brass cap which I have described, was strong enough to withstand the pressure from the air without, and thus allowed a vacuum to be formed within the tube. With a tube constructed in this way, and with an extreme exhaustion of the tube, Lenard was able to find rays outside the tube in the vicinity of the little aluminium window, and to examine the properties of these rays. He found that they could be made easily visible if caused to fall on small pieces of paper sensitised with luminous paint; and with the help of screens thus constructed, he was able to trace the paths of the rays, and to study them. He found that different bodies are very differently transparent to the rays, and showed that many bodies quite opaque to ordinary light transmit them with great freedom. Thus, wood and all the metals permit them to pass, and some bodies much more freely than others. The denser the substance the more does it obstruct the passage. For instance, lead is nearly opaque to them, while one of the materials which transmits them easiest is the very light metal aluminium. One more property which Lenard found I must refer to. It is well known that the cathode stream of particles is deflected in a very remarkable way by a magnet. This was shown by Crookes, following the older experimenters on the subject. Lenard showed that the rays which have come out of the vacuum tube through the aluminium window are similarly affected. This, as we shall see, is of great importance in considering the most recent discoveries, of which I have now to give you a very brief account.

Five weeks ago came the startling announcement that Professor Röntgen, of Wurtzburg, had been able to obtain radiations from the vacuum tube which could pass through great masses of solid and commonly-called opaque matter, and which could be detected

at great distances, and which, in fact, were not at all of the almost microscopic character of the rays investigated by Lenard. These rays have the property of acting very powerfully on certain fluorescent salts, and particularly on the salt known as platino-cyanide of barium. With a screen covered with this salt Röntgen has found the rays passing through a book of more than 1,000 pages, and at a distance of one or two metres from the tube. He also finds that they act with great power on ordinary dry photographic plates. He has been able to make shadow photographs of objects, which are opaque to these rays, through wood and through plates of aluminium which are very transparent to them. But perhaps the part of his discovery which has excited universal attention and astonishment is this, that the rays are differently affected by different parts of the animal body. The bones are much more opaque to the rays than the flesh and muscles. Thus, Röntgen has been able to produce a photograph of a human hand in which the bones are clearly shown, while only a faint image is given of the surrounding flesh. Through the kindness of Lord Kelvin, I shall be able to show you a series of original photographs by Professor Röntgen himself, which accompanied a copy of his original paper; and which, with the paper, reached Lord Kelvin a few days before the end of the year, and constituted the first announcement in this country, so far as I know, of this wonderful discovery. Lord Blythswood and Dr. Macintyre will also be able to show you results of their repetitions of Röntgen's experiments.

Röntgen has investigated very carefully the properties of these new rays, which he has provisionally termed X rays, on account of want of knowledge at the present time of their true nature. He has compared the transparency of various bodies for the rays, and, it appears, so far as has yet been discovered, that density is the main property which regulates transparency. It is not possible to say yet, however, whether or not the rays may be, by some means, broken up, and whether there may be in different bodies a quality corresponding to the *colour* of ordinary transparent substances. Bodies like wood, paper, and all sorts of organic substance, seem extremely transparent. Every one of the metals is more or less transparent, but the lighter the substance the more transparent it is. Thus, while aluminium and zinc are highly transparent, the bodies which are least transparent are lead, platinum, and the other heavy metals. Such want of transparency as there is appears to correspond with that which we ordinarily meet with

in muddy water, or in water which has had a little milk mixed with it.

So far as has yet been found, the rays are not refrangible. Röntgen has tried with lenses and prisms of various kinds but has not been able to detect any signs of refraction. Neither has he been able to detect any signs of true reflection. With regard to this latter point, however, some experiments of Lord Blythswood lead us to think that perhaps definite and true reflection may yet be found. It is to be remembered that the subject presents great difficulties because of the almost complete transparency of the bodies, from the surfaces of which reflection might be observed.

These rays are not found to be polarised by any of the ordinary means, and this fact has given rise to the conjecture that they may possibly be not of the nature of light waves at all. In waves of light the wave motion is transverse to the direction in which the light is being propagated; but we are familiar with waves also which are not transverse, and in which the movements of the particles are in the direction of propagation of the disturbance. Such are the waves of sound. Röntgen, in his paper, puts forward the suggestion that possibly the rays which he has discovered are longitudinal waves, of extremely short wave lengths, set up and propagated in the so-called luminiferous ether.

Lastly, Röntgen has found that these rays are not affected by the presence of a magnet. This is of great importance, because, as you will remember, I explained that the radiations with which Hertz and Lenard dealt are conspicuously affected by the magnet, and this last-mentioned property of the rays discovered by Röntgen seems to show that the Röntgen rays and the Lenard rays are different in kind.

I need hardly say that much yet remains to be done in the examination of this wonderful new subject. In the course of the next few weeks, or months, we may expect to know a great deal more about it than we can at all claim to know this evening.

II.—Lord Blythswood's Account of his Experiments.

His Lordship remarked that Dr. Bottomley having given an eloquent preface as to what was known with regard to the X rays, he was himself glad to bring before the Society a notice of some experiments which he had conducted in his own laboratory at Blythswood. For some time past he had been forced to believe that the haloid salts exposed on a sensitive

plate were acted on by an electric spark, and that, in fact, they were acted on more decidedly than would be the case with the same length of exposure to ordinary sunlight. Photographs of such sparks, taken in the five-hundred-thousandth part of a second, were what photographers spoke of as "over-exposed." In the autumn and winter of 1895 his Lordship had repeated the experiments of Herr Lenard, and produced the "brush" discharge through a thin plate of aluminium from a high vacuum into the open air. From the experiments referred to, he was led to believe that photographs could be obtained between the poles of a powerful Wimshurst induction machine, which he had some time previously made for himself. He found that such was the case, and photographs had been taken between the poles of his induction machine in light-tight boxes (which were exhibited). At the suggestion of Lord Kelvin, in order to make quite certain that the pictures produced were not an electrical effect, he used a thick zinc box, which was provided with an aluminium window. This box was placed between the poles of the machine, with metal objects, such as watch wheels, placed close to the photographic plate, under the aluminium window. The box was carefully "earthed," and the photographs came out clearly and well. This result seemed to be quite conclusive that the X rays could be produced in the open air by an electrical discharge of high tension. His Lordship did not pretend to say that this method was as good as that with a vacuum tube for what had been called "shadow photographs," but the interest lay in the fact that a vacuum was not necessary. He had produced good photographs in carefully-closed metal boxes, fitted with aluminium windows. These boxes were placed between the poles of the induction machine, carefully "earthed." The positive pole of the machine was also well "earthed." The object of all those arrangements was to prevent any probability of the photographs being produced by discharges inside the metal box, and the result seemed to be quite conclusive that without a vacuum tube the X rays could be excited in the open air.

III.—Dr. Macintyre on the Production of Shadow Photographs.

When the interesting subject of the Röntgen rays was first mentioned in the newspapers of this country, the description of the apparatus to be employed suggested great complications.

One read of ten to twenty thousand volts alternating current, Tesla coils with twelve Leyden jars, ten inches spark induction coils, and very highly exhausted Crookes' tubes. With the current from the street electric main supplied from the 100-volt circuit in Glasgow, it was quite evident that transformers for such work could not be made either portable or inexpensive. As these considerations were of great importance in surgery, I thought it advisable to make a series of experiments with much simpler apparatus, and the result has been attended with some success. In to-night's demonstration I will show the apparatus, and project upon the screen a number of the photographs taken.

The apparatus consists of a small secondary battery, giving eight volts and six amperes; an induction coil, lent by Professor Jamieson; a very small Tesla coil, made by Messrs. Baird & Tatlock; and a Crookes' tube, which was selected from the stock of Mr. Otto Müller, of Glasgow. With these one is able to demonstrate all the ordinary phenomena of photography of objects through wood, aluminium, black cardboard, &c., &c.

APPARATUS REQUIRED.

1. *The Source of the Current.*—It is difficult to say in a general sense what is the best source for such work, especially when we consider that portability is an essential element in surgical practice. Those who have the current supplied from the street mains have a considerable advantage, so long as the work is to be done in the laboratory; but Bunsen's and Grove's cells, giving the necessary voltage and amperes to excite the coil, can easily be obtained. In my own experiments I use the current from the main, but, given an induction coil requiring a certain voltage and ampere of current, one can easily obtain a primary or secondary battery sufficient for the purpose. Naturally, if cells be used, those which do not polarise rapidly are the best, and hence my choice of four ordinary E.P.S. cells, failing which, however, I have used a battery of the Bunsen type.

2. *The Transformer.*—This, the second part of the apparatus, is a very important one. Various kinds of transformers are at our disposal, but the common one is some form of induction coil. The one on the table gives a six inches spark, and where it can be obtained even a larger coil is of service.

3. *The Tesla Apparatus.*—I wish here to point out that the Tesla coil is not essential, but it is useful to those who are

employing a small induction coil, because of the increase of voltage and frequency of discharge which it produces. In the experiments under consideration I have used a small Tesla coil for this purpose, and it has answered admirably.

4. *The Crookes' Tube.*—Probably the most important part of the apparatus is a good Crookes' tube of high vacuum. The one which I have used with greatest success so far is the old form with four poles, but different patterns must be tried. Through the kindness, and acting upon the advice, of Dr. Bottomley, I am having a number of these made by Mr. Otto Müller, but we are so far in the experimental stage only. At present it is very difficult to get suitable tubes for this particular purpose, so that I was forced to make a selection of what could be found in the instrument-maker's stock.

With the apparatus which I have mentioned and described, all the ordinary phenomena spoken of in the journals may be demonstrated, and with it I have photographed coins through the ordinary camera slide, the shutter of which was three-sixteenths of an inch thick. I have also passed the rays through aluminium plates, cardboard, and wood.

PRACTICAL WORKING OF THE APPARATUS.

1. *Method of Placing the Object to be Photographed in Relation to the Sensitised Plate.*—Having selected the object to be photographed, it should next be placed as near as possible to the sensitised surface of the plate. If it be a flat object it may be placed directly in contact, so that a sharp picture may be obtained. On the other hand, certain objects cannot be placed in contact because of their thicknesses, and therefore it is better to enclose the sensitised plate between layers of thin material, such as wood or paper, which will prevent it being acted upon by ordinary light. Care should be taken, however, to place the object as near the plate as possible, and to remove the Crookes' tube to some distance from the plate.

2. *Where to Place the Object.*—The object should be placed between the tube and the sensitised plate, and by carefully watching the fluorescence of the tube, or by testing, photographically, one can discover where the greatest number of X rays are generated. For example, in the tube seen on the table the negative pole is placed directly upon, or in front of, the object to be photographed, and when the current is switched on a

greenish fluorescence on the glass is observed directly opposite the cathode. The object to be photographed is placed in front of or below this,—in other words, in the course of the X rays, so that these may be absorbed in their passage from the tube to the sensitive plate.

3. *Length of Exposure.*—This, of course, will depend upon many things—first of all, upon the current at our disposal, on the coil, on the number of interruptions per second, and particularly on the tube used; and, lastly, on the character of the sensitive plate itself. At first my exposures were as long as forty minutes, but since then the time has been greatly reduced.

4. *Photographic Material.*—The most of my experiments have been made with Paget xxxxx plates, but I have also used others. It is not unlikely, however, that a good deal yet has to be done in finding more suitable plates. In developing I have used hydrokinone, but with bromide paper the ordinary iron solution. Beyond this the details are simply those of ordinary photographic work.

This art, of course, is in its infancy, and consequently every worker will meet with difficulties; but my experience has led me to think that they will be easily overcome. Indeed, our present difficulties may in the end be found to be an advantage, owing to the constancy of the factors which produce the picture, not as in the case of sunlight, which is constantly varying.

I feel quite confident that the apparatus will soon become very much more simple than can at present be conceived, and that before long a portable and comparatively inexpensive apparatus will be at the disposal of the surgeon.

GLASGOW SCIENCE LECTURES ASSOCIATION TRUST LECTURE FOR SESSION 1895-96.

XIV.—*Part I.—On the Ben Nevis Observatories and the Work done there.* By ALEXANDER BUCHAN, M.A., LL.D., F.R.S.E., Secretary of the Scottish Meteorological Society.

[Delivered before the Society, 19th February, 1896.]

(WITH PLATE III.)

THE science of meteorology deals with that department of natural philosophy which treats of the phenomena of the atmosphere comprised under climate and weather. These phenomena relate to the action of the forces on which the variations of pressure, temperature, humidity, and electricity of the atmosphere depend, but, in an especial sense, to the aërial movements which necessarily result from these variations. In the historical development of the science the investigation of climate long preceded that of weather.

Humboldt made the first great contribution to this science, in his work on "Isothermal Lines," which was published in 1817. Dove continued and extended that investigation, and, in his great work "On the Distribution of Heat on the Surface of the Globe," published in 1852, gave maps showing the mean temperature of the earth for each month and for the year. To this, more than to any other work, belongs the merit of having popularised the science of meteorology in the best sense, by invoking to its service troops of observers in all parts of the civilised world.

There was published another series of maps in 1868, representing by isobaric lines, or lines of equal atmospheric pressure, the distribution of the mass of the earth's atmosphere, and by arrows the prevailing winds over the globe for the months and the year. By these maps the movements of the atmosphere and the immediate causes of these movements were, for the first time, stated, and thus a real knowledge was obtained of some of the more difficult problems of meteorology. It was shown that prevailing winds

were the simple and inevitable result of the relative distribution of the mass of the earth's atmosphere—that is to say, of the relative distribution of its pressure,—the direction and force of the prevailing winds being simply the flow of the air from a region of higher towards a region of lower pressure, or from where there is a surplus to where there is a deficiency of air. It is on this broad principle that meteorology rests; and the principle is found to be of universal application throughout the science, in explanation not only of prevailing winds, but of all winds, and of weather and weather changes generally. One of the more important practical uses of the principle is in furnishing the key to the climates of the different regions of the earth, since climate is determined by the temperature and moisture of the air; and these, in their turn, are dependent on the prevailing winds which come charged with the temperature and moisture of the regions which they have traversed. The isobaric lines show, further, that the distribution of the mass of the earth's atmosphere depends on the geographical distribution of land and water in their relations to the sun's heat, and to radiation towards the regions of space at different seasons of the year.

In 1882, Professor Loomis, of Yale College, U.S., published a map showing the mean annual rainfall over the globe. This map, and others that have been constructed, representing the amount of the rainfall for the months and for the year, show, conclusively, that the rainfall of any particular region, or particular locality, is determined by the prevailing winds considered in their relation to the regions from which they have come, and the physical configuration and temperature of the part of the earth's surface over which they blow. It is abundantly proved that the maximum rainfall is precipitated by winds which, after having traversed a great breadth of ocean, come up against and blow over a mountainous ridge lying across their path; and the amount deposited is still further increased if these winds pass at the same time into higher latitudes through regions the temperature of which is constantly becoming colder as they advance over it. On the other hand, the rainfall is unusually small, or often nothing at all, when the prevailing winds have not previously traversed a considerable extent of ocean, or have previously crossed a mountain ridge, and are now, in either case, advancing into lower latitudes, or into regions whose temperature is becoming markedly higher as they advance over it.

The branches of meteorology just referred to—namely, the geographical distribution of atmospheric pressure, temperature, prevailing winds, and rainfall, together with the results which flow directly and immediately therefrom—comprise in their scope the constituent elements of climate. Meteorologists are now in a position to claim that, through their labours, the climates of all the habitable regions of the earth are well known, or at least known with close approximation. The labours by which this great result has been achieved can only be described as truly herculean, whether regard be had to the myriads of observers, whose patient and long-continued work of observing has contributed the data, or to the toilsome years spent by specialists in discussing these data, and giving the results on maps of the globe in the clear and simple form in which they now lie before us, so simple that "he who runs may read." Indeed, the only large region of the globe where observations have not yet been made from which the geographical distribution of pressure, temperature, humidity, and prevailing winds for the month and for the year may be determined, is Antarctica. Of this important part of the earth little is known as to its meteorology, except for one or two restricted regions during the summer months. There can be no doubt that in the near future these great blanks will be filled up, and thereby most important scientific and practical problems be solved regarding the meteorology and magnetism of the globe, and, above all, oceanic circulation.

During the past year two contributions have been made to oceanic circulation, one of these being the last paper which is published in the volumes of the *Challenger* Reports. The other has just appeared in the *Transactions* of the Royal Society of Edinburgh. The results contribute invaluable additions to the climatologies of important regions of the earth; and, with more or less precision, define for the first time, what may, by analogy, be called the climatologies of the ocean, from the surface, through its various depths, to the bottom.

But while the data for the determination of the geographical distribution of the prime elements of climate were being slowly but surely collected, the great importance of the study of weather came gradually to be recognised. A special impetus was given to this branch of study from its intimate bearings on the eminently practical question of storm warnings and weather forecasting. Undoubtedly, one of the first problems of meteorology is to

ascertain the courses which storms take in passing over the earth's surface and the causes by which these courses are determined, in order to deduce from the phenomena observed, not only the certain approach of a storm, but also the particular course which that storm will take. The method of practically conducting this large inquiry from day to day, and in the most effective manner, was devised by the genius of Leverrier, the prince of meteorological organisers, and was begun to be carried out in 1858 by the publication of the daily *Bulletin International,* to which a weather map was added in September, 1863. Such maps, now issued by many governments, show graphically, for the morning of the day of publication, the atmospheric pressure, the direction and force of the wind, temperature, rain, cloud, and sea disturbance over Europe. From these maps forecasts of weather are framed and storm warnings issued. But, in addition to this, a body of information in a very handy form is being collected, the careful study and discussion of which is slowly, but surely, leading to the issue of more satisfactory and exact forecasts, and to a more certain knowledge of those great atmospheric movements which form the groundwork of meteorology.

Many results of the first importance have been established from discussion of weather maps, of which the following may be here referred to:—All winds are caused by differences of atmospheric pressure, just as the flowing of rivers is caused by differences of level—the motion of the air and the motion of the water being both referable to gravitation. The wind blows from a region of higher towards a region of lower pressure, but all observations show that the movement of the air is not directly to the area of lowest pressure, but vorticosely round and in upon that area. From this behaviour of the wind Buys Ballot's Law was declared, which runs thus: Stand with your back to the wind, and the lowest barometer, or centre of depression, will be to your left in the northern hemisphere, and to your right in the southern hemisphere. The law is then of universal application throughout the science, in explanation, not only of prevailing winds, but also of all winds, and of weather and weather changes generally. It is one of the broadest generalisations of science yet reached. In truth, no other science dealing with purely terrestrial phenomena can show a broader.

It is the application of this principle to the winds of the cyclone and the anti-cyclone which furnishes an intelligent

understanding of weather changes. Speaking generally, stormy winds, a large rainfall, and broken weather are the accompaniments of the cyclone; whereas light winds and fair and settled weather accompany the anti-cyclone. But the relations of these two distinctly and essentially different types of weather conditions to temperature and temperature changes require a more detailed account, particularly those of the cyclone.

First, let us deal with the cyclones of Europe, which more immediately concern us. While the winds are observed to blow vorticosely towards, and in upon, their centres, none of these winds as they sweep along the surface of the earth ever make a complete circuit of the whole of the central area of the cyclone, and this fact, very often lost sight of, must be kept steadily in view. All observation shows that on the east side of an advancing cyclone, where winds are from east-south-east, south, and south-west to about west, the atmosphere is warmer and moister than it is in the rear of the cyclone, where winds are from west-north-west, north, and north-east to about east-south-east, where the atmosphere is colder and drier. It looks as if the cyclone held its course between two great atmospheric currents, differing widely from each other in the all-important climatic conditions of temperature and moisture—a view strongly urged by Dove. Thus to the south of the easterly track of the cyclone is a vast, powerful equatorial current, characterised by high temperature and much cloud and rain; whereas on the north side of this track there is a vast polar current, accompanied with great cold, clearer skies, and intermittent rather than continued rain.

Since these differences are more pronouncedly contrasted in the winter months, it goes without saying that the winter is a mild and open one when the cyclones of North-western Europe pursue their eastward courses along tracks lying quite outside the west and north coasts of the British Islands; and, on the other hand, the winter is a hard one, with frost and snow, when the cyclones of North-western Europe pursue their eastward courses along tracks lying completely to the south of us—we being thus, in the latter case, within the great polar current on the north side of the storm's track. Now, to this broad statement meteorology is cognisant of no exception—again one of the broadest results of any science. It thus follows that the meteorologist can, without the possibility of a mistake, lay his finger on the immediate cause or causes of hard and mild winters respectively.

In the summer months it is seldom that cyclones show the extent and depth of the winter cyclones, the usual cyclone being of much smaller extent and of much shallower depth. A succession of such cyclones passing along the English Channel, or through England, into the North Sea, moving slowly there in their easterly course, or lingering there for days—barometric pressure at the same time being higher in the north of Scandinavia, Faröe, and Iceland, than in Scotland,—are the invariable meteorological conditions which give us our very worst summer weather. Of this type of weather the latter half of July, 1867, is as good a specimen as could be adduced. Then the mean temperature of Scotland was only 49°·0, which is the average summer temperature of the north of Iceland; sunshine was unprecedentedly small, and cloud unprecedentedly large, and the rainfall came in deluges in eastern districts that were not protected by hills from the north-easterly winds which brought the rain.

It is during the large cyclones, occurring chiefly in the autumn and winter months, that the heavy rains are precipitated over the western districts, sometimes extending no farther east than the watershed of the country, but more frequently pouring a copious rainfall over eastern and western districts alike. On these occasions the winds on the top of Ben Nevis and at sea level blow in the same directions.

On the other hand, the weather concomitants of the shallower and less extensive cyclones are widely different from those just indicated. From July to November very heavy rains not unfrequently occur with these cyclones when their centres are in England or to the eastward, over the North Sea. In truth, by far the heaviest downpours which ever occur in the east of Scotland occur under these conditions, when it is not uncommon to collect two or three inches of rain in 24 hours; and even the phenomenal amount of four inches has been collected. But these enormous rainfalls do not penetrate far inland.

Now, in such cases, the winds at the top of Ben Nevis blow in a direction approximately the opposite of the direction in which they blow at sea level. To put this most important matter in another view, the winds at the top of the Ben are not, then, part and parcel of the great vorticose aërial movement directed in upon the adjacent cyclone—that is to say, they are outside the influence of this cyclone, being above that influence. On the contrary, they blow approximately towards the neighbouring anti-cyclone,

precisely as the upper currents of the atmosphere are observed to blow in the direction of anti-cyclones. The important consequence follows, that here we have the cyclone in its whole height comprised in the aërial stratum between the observatory at Fort-William and the observatory at the top of Ben Nevis, thus opening up a splendid field of weather research on this mountain —a research which would be immensely expedited if the directors were able to establish, for temporary purposes, a third observatory on the top of Meall an t' Suidhe, which is situated nearly midway in height between the two observatories.

There is another type of weather in which the less robust among us are specially interested—to wit, the dry east winds of spring, which are frequently an accompaniment of the shallower cyclone now under consideration. When this happens Scotland is outside the rain area of the cyclone. The wind is then easterly; and as it comes to us across the North Sea, which is at the time near its minimum temperature for the year, it is cold, and often laden with fog. But as it advances over the land, the fog melts away, the clouds disappear, the sun pours a strong heat over the land, the air itself gets heated, and thus, long before the east wind reaches Glasgow, it has lost the peculiar virulence which it has in the east. The weather of June, 1895, may be cited as an illustration. In that month barometric pressure was higher at western than at eastern stations, and, as a consequence, north-east and north winds were considerably above the average. At Aberdeen the mean temperature of the month was half a degree under the June average, whereas at Glasgow, which these easterly winds reached only after a long journey over the heated land, the mean of the whole month was two degrees above the average; and, it need scarcely be added, that on the particular days when these winds prevailed, the difference of temperature in favour of Glasgow, as compared with the east of Scotland, was very much greater.

Weather forecasting is of two distinct kinds—namely, forecasting the weather of the coming season, and forecasting the weather a day or two in advance. Forecasting the general character of the weather of the coming season has been attempted with some measure of success in India, in connection with the monsoon rains, upon which so much depends. It has been found that an unusual breadth of snow covering the face of the country to the north, during the winter months, changes the geographical

distribution of the barometric pressure, and this change in the distribution of the pressure is accompanied with corresponding changes in the amount and distribution over the country of the succeeding monsoon winds and accompanying rainfall.

Let me here interpose the remark that the whole question of forecasting weather may be said to consist absolutely in an ability to forecast the amount and the distribution of the barometric pressure over the region to which the forecast is applicable, together with the regions immediately surrounding it. Thus, suppose a large anti-cyclone to extend from the south of France northwards through Germany, Denmark, and Scandinavia, having the British Islands distinctly on its western side, then we certainly would have steady southerly winds, fine weather, and high temperature for the season. But, on the other hand, suppose the anti-cyclone to shift its position considerably to westward, so that now the British Islands are situated clearly on its east side, then, inevitably, north-westerly winds would sweep over these islands, bringing with them unseasonably cold, disagreeable weather.

Again, let us suppose that the daily weather map shows, by a slight drop of the barometer in the west, with a shift of the wind to southward, the existence of a cyclone out in the Atlantic advancing eastward, then, if it follows its easterly course along a path well to westward and northward of Scotland, and throughout its course the isobaric lines in Scotland are well apart from each other, it would be attended with fine weather and comparatively light winds. But let its course be across England and thereafter the North Sea, the isobarics close together, then a severe northerly storm would overspread with heavy rain or snowfall in eastern districts; and if its passage across the North Sea be slow, or if, as occasionally happens, it remains stationary or assumes a retrograde course to westward, the storm would be not only severe, but might be prolonged for days together.

Only a few years after the beginning of the daily issue of weather maps for Europe in 1863, it was proved to the hilt by the facts thus collected that the solution of the whole question of weather forecasting was really restricted to one point—namely, a tolerably correct knowledge of the geographical distribution beforehand of the barometric pressure.

Now there are two features in the natural history of the cyclone which make the difficulty of arriving at this knowledge with the accuracy required. These are (1) the changes which occur in the

direction of the line of onward movement taken by the cyclone; and (2) either the development of increased intensity as the cyclone advances, or the dying out of the cyclone altogether.

The average direction in which our storms of North-western Europe advance is approximately toward east-north-east; but experience has shown that deviations from that course, or from the course which the cyclone is pursuing, can be obtained from closely watching the behaviour of the anti-cyclone near it, when that anti-cyclone is within the meteorological field of observation. Thus, let the anti-cyclone be to the south of the British Islands, over Spain, as is often the case, and commence a decided movement to the south-east, then the cyclone which had been advancing towards east-north-east will, in closely hugging the anti-cyclone on its right, also change the direction of its onward course, and will now advance toward the south-east, over the Continent. The comparatively few exceptions to this rule well deserve the most elaborate investigation.

Take another illustration. Suppose an imperfectly-developed cyclone in the Baltic gradually to become well developed, so as to exhibit a low barometer at the centre, surrounded with isobarics close together, and, while this change has been proceeding, the barometer rises rapidly to the north, so that a well-marked anti-cyclone is now to the northward of the cyclone, the easterly onward movement of the cyclone no longer holds good, but, on the contrary, it advances, generally at a slow rate, towards the west, in obedience to the apparent law of these phenomena, that the cyclone in its onward course closely hugs the anti-cyclone on the right. These are strictly the meteorological conditions which bring about the great easterly storms of Central and Northern Europe, which, owing to the slow westerly movement of such cyclones, often last for days together. The discovery of this probable law, and its application to our systems of weather forecasting, has materially improved the forecasts of recent years.

But not many years elapsed after weather maps were circulated when meteorologists began to recognise the fact that, important as the results obtained from low-level observations were, such observations, taken by themselves, were altogether insufficient for the investigation of the problem of weather forecasting, the reason being that by this method the vertical variations and vertical gradients of the meteorological conditions were not taken account of. It is plain that this can be done only by having regular

observations at two stations as near one another as possible on the map, but differing as much as possible in elevation.

For the obtaining of this indispensable information, high-level observatories for meteorology began to be established in France, Switzerland, Austria, Italy, Germany, the United States, and other countries. Up to the present time the establishment of these observatories still continues. Among the latest may be mentioned one in Herzegovina, at a height of 6,762 feet; and we are all familiar with the daring which has placed one on Mont Blanc. For some years only three or four observations a day were attempted, but now, at no inconsiderable number of them, hourly observations are conducted. At Pike's Peak, in Colorado, the highest of all high-level observatories in the world, 14,134 feet high, hourly observations began to be made on September 9th, 1892.

For several years Great Britain did nothing towards the development of this all-important department of meteorology. The Council of the Scottish Meteorological Society took up the subject in 1877, but nothing really was done till 1881, when Mr. Clement Wragge heroically undertook to climb Ben Nevis daily during the summer months of that year, and make observations at the top; arrangements being effected that observations be made at Fort-William at the same times. In the following year a second series of observations, on a more extended scale, and arranged on the method proposed by the late Mr. Thomas Stevenson, was made by Mr. Wragge and his assistants. This scheme consisted in having eight stations at different heights on the side of the mountain, at which readings were made both on the outward and homeward journeys, and simultaneously with these at Fort-William, amounting to twenty-one daily, from 5 a.m. to 9 p.m. These observations were elaborate and complete, and were carried out by Mr. Wragge with a skill, energy, undaunted resolution, and success worthy of all praise. A similar, though not quite so elaborate a set, was carried out in 1883.

But meantime the observations of 1881 and 1882 were discussed with results of the greatest interest and value, which gave conclusive evidence of the correctness of the high expectations which had been formed regarding the part to be played by a high-level observatory on the peak of Ben Nevis in the further development of meteorology of North-western Europe, particularly as regards the practical question of forecasting the weather of the

British Islands. About the same time an unsolicited offer was received from the Meteorological Council of the Royal Society of London of £100 annually towards the support of the observatory.

An appeal was accordingly made to the public, early in 1883, for funds to enable the society to build an observatory on the summit of Ben Nevis. The greatest interest was manifested in the proposal by scientific men both at home and abroad; and the interest of the public was shown by a prompt response to the appeal made for subscriptions. In a surprisingly brief time upwards of £4,000 was collected, the subscriptions varying from £200 to a penny, and the list of subscribers included all ranks from Her Majesty downwards.

The observatory was built in the summer of 1883, and was formally opened on October 17th by Mrs. Cameron Campbell, who had granted the site for the observatory. The regular observations were begun in the following month, and have since been carried on every hour, night and day, summer and winter, with scarcely a break, for these thirteen years.

The essential difference between this observatory and low-lying observatories lies in this, that, while at low levels the hourly observations of temperature can be obtained by self-registering instruments, at the Ben Nevis Observatory eye observations alone are possible. The reason for this will be at once seen from the lantern slides to be shown by Mr. Omond. This being the case, it was absolutely necessary that the staff at the top should not be fewer than three men. The low-level station at Fort-William was near the sea, 29 feet above mean sea level, and the observations were made by Mr. Colin Livingston. Both stations were furnished with the best instruments that could be obtained.

From the commencement the two lines of inquiry which the directors kept steadily before them were these: in the first place, to make simultaneous observations both at the top and at the foot of the mountain, and discuss them in their purely scientific aspects; and, in the second place, to deal with the facts and the results thus obtained, so as to lead to more accurate methods of framing forecasts of coming weather.

Two vital problems first claimed attention. The first of these was the ascertaining of the mean monthly and annual temperature of each of the stations, from which the rate of diminution of temperature with height might be known from the actual observations. This problem presented no difficulty, nothing but the

heavy continuous labour of calculating being required. From the first three years' observations, the rate of diminution of temperature with height was ascertained to be one degree Fahr. for every 270 feet of ascent. The second problem was to ascertain the differences between the mean pressures of the two stations at all observed temperatures and at all observed sea-level pressures. The object sought to be attained was a better knowledge of the rate of diminution of pressure with height under the varying conditions of season and weather, and to construct therefrom a Table of Corrections for height, in order to reduce the observations of pressure to sea level. This problem presented peculiar difficulties.

Scarcely a step could be taken in the further investigation of the observations till these two problems had been settled.

Thereafter various inquiries were set on foot, and, as these were proceeded with, it became more and more apparent that the great objects aimed at by the Ben Nevis Observatory could not be attained unless a low-level observatory were established at Fort-William, at which hourly observations were made as at the top of the mountain. With the aid of the Meteorological Council of London, such an observatory was formally opened in July, 1890, and, since then, hourly observations at the top and foot of the mountain, for the various discussions, are carried on.

The following are the more important of the investigations, with the aid of the very full observations obtained from the two observatories:—Mean hourly values for each month and for the year of atmospheric pressure, atmospheric temperature, rainfall, cloud, and wind have been determined. As regards the hourly velocity of the wind, observations show that the maximum velocity occurs, as in the case of all high-level observatories situated on a true peak, during the night, when temperature is lowest, and the minimum velocity during the day, when temperature is highest, this result being the reverse of what obtains at low-level observatories and stations.

In valuing the observations made at the top of the "Ben," considerable trouble was experienced from the "pumping" of the barometer, this pumping increasing with the increase of the force of the wind. The result is a continued lowering of the recorded pressure below what prevails at the time if calm or light winds only prevail. It was necessary, from the great importance of the

points involved, to ascertain the rates at which pressure is lowered with different wind velocities.

At the high-level observatory the wind is observed in two ways —by estimation by a scale 0 to 12, and by an anemometer, specially designed by Professor Chrystal, showing the velocity in miles. The following summarises the results, showing the depression of the barometer with each wind velocity, both barometers having been reduced to sea level from each hour's observations :—

Beaufort's Scale. 0 to 12.		Equivalents in Miles per Hour.		Baro. Depression. Inch.
0	...	2	...	−0·001
1	..	7	...	−0·004
2	...	13	...	−0·005
3	...	21	...	−0·010
4	...	29	...	−0·014
5	...	38	...	−0·026
6	...	47	...	−0·035
7	...	57	...	−0·050
8	...	67	...	−0·070
9	...	77	...	−0·104
10	...	88	...	−0·126
11	...	99	...	−0·150
11 to 12	...	111	...	−0·170

Thus, in calm weather, the two reduced barometers are practically the same, but with every increase of wind the depression of the barometer steadily augments. It is not till a velocity of more than 20 miles an hour is attained that the depression amounts to one hundredth of an inch. At 57 miles an hour it is 0·050 inch; at 77 miles, 0·104 inch; and at 111 miles, 0·170 inch. Velocities, for brief intervals of time, exceeding 150 miles an hour, have been noted when the depression nearly reached 0·300 inch.

This depression of the barometer is doubtless occasioned by the wind driving out the air from the room where the barometer is hung as it rushes past the observatory, thus causing a partial vacuum, and consequently a lower pressure. If a window or door is opened on the side of the room exposed to the wind, the readings of the barometer are thereby raised; whereas on the leeside of the buildings, in rooms connected therewith, and in rooms with chimneys, barometric readings are lowered.

Winds from each of the sixteen points of the compass were examined, with the remarkable result that the highest velocities,

or velocities exceeding 70 miles an hour, were absolutely restricted to the points of the compass from S.E. by S. to E. by S.; but that from S.N.E., E., W.N.W., N.W., and N.N.W., no observations of the winds had been recorded exceeding 29 miles an hour.

The mean monthly and annual directions of the wind have been calculated, with the all-important result that the direction of the wind on the top of Ben Nevis differs essentially from the observed direction of the wind at all low-lying stations in that part of Scotland. In striking contrast with this result is the fact that, at high-level observatories on the Continent, the mean direction of the wind is substantially the same as what obtains at low-lying stations in the neighbourhood of these observatories. This great and striking difference is the simple consequence from the position of Ben Nevis being in the path of the cyclones of North-Western Europe, thus giving the observations made at the two Ben Nevis Observatories a unique significance in all investigations into the weather of this part of the globe.

The mean difference between the temperature at the two observatories is 16°, but the differences on individual days differ widely from this average. At the top of the "Ben," temperature has been noted 28° lower than at Fort-William at the same time; and, on the other hand, on 19th February, 1895, temperature at the top was 17°·8 higher than at Fort-William. In the former case, temperature instead of being 16° lower at the top was 28°, or a difference excess of 12°; but in the latter case, instead of being 16° it was 17°·8 higher, thus showing a deviation of 33°·8. These relatively high temperatures at the top are all accompaniments of the anti-cyclone, and show, in a most impressive manner, that it is not the cyclone, but the anti-cyclone, which occasions the greatest deviation from the average in the vertical distribution of temperature, and, it may be added, also in the vertical distribution of humidity.

Now, these departures from the normal vertical distribution of temperature and humidity are accompanied with well-marked peculiarities in the differences of the sea-level barometric pressures of the two observatories. These relations of pressure and temperature have been elaborately investigated and determined. The results are summarised in the following table, which shows, for each 2 degrees difference of temperature, the difference between the reduced barometer at the top and the barometer at Fort-William—the plus sign indicating that the top temperature or

the top barometer was the higher of the two, and the minus sign that it was the lower :—

Difference of Temperature.	Difference of Pressure. Inch.	Number of Comparisons made. Upper Barometer was— Higher.	Lower.	Total.
+ 6° to + 4°	+ 0·047	5	0	5
+ 4 ,, + 2	+ 0·044	13	0	13
+ 2 ,, + 0	+ 0·041	19	0	19
− 0 ,, − 2	+ 0·031	18	0	18
− 2 ,, − 4	+ 0·020	13	3	16
− 4 ,, − 6	+ 0·009	38	15	53
− 6 ,, − 8	+ 0·011	76	21	97
− 8 ,, − 10	+ 0·009	160	50	210
− 10 ,, − 12	+ 0·006	280	122	402
− 12 ,, − 14	− 0·001	378	312	690
− 14 ,, − 16	− 0·005	323	677	1,000
− 16 ,, − 18	− 0·010	241	802	1,043
− 18 ,, − 20	− 0·017	66	722	788
− 20 ,, − 22	− 0·023	15	414	429
− 22 ,, − 24	− 0·026	0	204	204
− 24 ,, − 26	− 0·029	0	50	50
	Total,	1,645	3,392	5,037

The broad result is this, and it is clear and explicit, when the higher observatory has the higher temperature, and when the differences of temperature at the two observatories are small, then the reduced pressure for the top of the mountain is the greater of the two; but, on the other hand, when the differences of temperature are very large, the top of the Ben being the lower of the two, then the reduced pressure at the top is the less of the two. The regular progression of the figures in the table shows that what is substantially a true mean has been arrived at. This result was altogether unexpected, and it is suggestive of questions affecting the theory of storms, the effect of vertical movements of ascending or descending masses of air on the barometric pressure which accompany changes of weather brought about by anti-cyclones and cyclones, and emphasises the necessity which exists for a better knowledge of the absolute amounts of aqueous vapour at different heights in the atmosphere under different

weather conditions, and how far this knowledge may be arrived at from the readings of the dry and wet bulb hygrometer.

In this connection the remarkable weather of the 28th, 29th, and 30th of September, 1895, which was eminently anti-cyclonic, has been examined. On these days the air at the top of the mountain was phenomenally warm and dry, and this state of things was continued half-way down the hill; whereas lower down to sea-level, temperature was also high, and the air close to the point of saturation. Now, in these circumstances, since moist air is specifically lighter than dry air, it follows that, from sea-level to upwards of 2,000 feet high, the air was specifically lighter than at greater heights, and consequently the reduced barometer at Fort-William, reading lower than it would otherwise have done, gave a relatively higher reduced barometer for the barometer at the High-Level Observatory.

Since similar investigations of the phenomena during cyclones show reversed barometrical results, it may fairly be concluded that the Ben Nevis Observatories open up new lines of inquiry, the prosecution of which is likely to give a more exact knowledge of what our American collaborateurs call the increasing or diminishing of the intensity of approaching cyclones and anti-cyclones.

During the past four years there has been carried on a large inquiry on the influence of fog or cloud and clear weather, respectively, on the diurnal fluctuations of the barometer. At both observatories the curves of diurnal barometric fluctuation for fog on the one hand, and clear weather on the other, are markedly different from each other. The outstanding difference respects the ordinary evening maximum, which in foggy weather is from four to six times greater than the same phase of the curve in clear weather. The inquiry has been extended to observatories and stations on the Continent, the tropics, and the Arctic regions, the results of which are congruent with the Ben Nevis results.

Another subject more immediately under discussion is the daily rainfall, and its distribution over the different districts of the country. The observations of the daily rainfall at 120 stations, well distributed over Scotland, from July, 1890, when the Low-Level Observatory was fully equipped, to December last, have been copied out on monthly sheets. The results are being carefully compared with the Bi-daily Weather Maps issued by the

Meteorological Office. Attention has been drawn in the previous half-yearly Reports of the Council to the totally diverse distribution of rains with easterly winds and westerly winds respectively; and also to the direction of the wind at the top of Ben Nevis compared with the winds at sea-level at the same time, as giving an indication of the depth of the barometric depression and extent of a coming cyclone. Now, it is on these lines that the problem of forecasting rains, more particularly the geographical distribution of very heavy rains, is being prosecuted.

A discussion of the two sets of observations at the two observatories in their bearings on the storms and weather of North-western Europe has been in progress for some time. The following is a sketch of the method adopted:—The subject is divided into these several parts—cyclones; anti-cyclones; unusually small differences of temperature between top and bottom, including inversions of temperature; large differences of temperature; great dryness of air at the top; marked differences of wind at top and bottom, either as regards direction or force; the rainfall above and below; relations to storms reported at the lighthouses; conditions under which very diverse readings of the two barometers occur. In each of these cases the Daily Weather Charts and the Weather Charts of Europe at the time are examined. Thus, for example, in dealing with cyclones, the following data are entered in the columns of the sheet for the investigation of cyclones: the position in Europe of the cyclone; position of the nearest anti-cyclone at the time, with its highest barometer; the direction, whether N., N.E., E., &c., Ben Nevis is from the cyclone; its distance from the centre of the cyclone in miles; the temperatures at the observatories; the humidities at ditto; the sunshine and cloud; the barometer at sea-level at Ben Nevis, with lowest barometer at centre of cyclone, and its position; wind at sea-level and top of mountain; storms at lighthouses; and the distribution of rainfall over Scotland.

It will be observed that there is in all this work an unmistakable recognition of the fact that the problem of the weather is an excessively difficult one, and that the method adopted in dealing with it is solely through the facts of observations made at numerous stations, well distributed over Scotland, at sea-coast and inland situations, and at various heights up to 4,406 feet.

Part II.—Life and Observing at the Ben Nevis Observatory.

By R. T. OMOND, F.R.S.E., Superintendent.

WHEN the Observatory on the summit of Ben Nevis was built, it was resolved by the Directors that it should be a meteorological station of the first class—that is to say, one whose records should give hourly values of the barometer, temperature, wind, rainfall, cloud, and sunshine. All mountain observatories previous to that time had been second-class stations, at which observations of these data were made only at certain fixed hours each day, helped, in some cases, by tracings of such self-registering instruments as could be used in these isolated situations. The first winter's experience on Ben Nevis showed that a continuous record could only be got by direct eye observations at each hour, as no self-recording instruments of sufficient delicacy to give the wind, temperature, humidity, and rainfall accurately could be trusted to work in such a climate; and, since May, 1884, hourly readings by day and night have been taken. The following are the arrangements by which this became possible :—

(*1*) *Buildings.*—To the original oblong hut that was erected in 1883 there was added in 1884 an extension, consisting mainly of an office-room and a tower. The former made it possible to tabulate the observations and do computing work in a far more complete and satisfactory manner than formerly, while the latter served many purposes. A door near the top allows the observers ready communication in and out when the main building is buried in snow; on the roof anemometers are placed, and the upper storey, which has windows all round, makes a convenient outlook under cover.

(*2*) *Instruments.*—The thermometers are exposed in double-louvred screens (slightly smaller than the ordinary Stevenson screen), which are kept at approximately the standard height of four feet above ground by being attached to upright stands shaped like ladders, on the successive steps of which the screen can rest. Duplicate screens and instruments are in use, so that when one set become choked with snow, they can be removed bodily and replaced by a fresh set. Duplicate rain or snow gauges are also used. These are cylindrical in shape, widening out below into a

rounded base, so as to be easily levelled when resting on snow. One is taken out each hour, the previous one containing the hour's fall being brought in and measured at leisure inside. The wind is estimated in direction and pressure by the observer when out, his values being checked by the readings of an anemometer when the weather allows.

(3) *Personal.*—All these arrangements, it will be seen, necessitate the presence of an observer at each hourly reading. There are, therefore, two men engaged in this work. The day is divided into watches, eight hours long at night and four hours during the day, so that each observer has twelve hours' duty out of the twenty-four. The actual observation only takes about five or ten minutes, but during the remainder of the time there is plenty to do in entering up observations, averaging the previous day's records, and preparing the monthly tabulations and summaries.

This steady routine of hourly observations has gone on now for nearly twelve years without a break, except on one or two occasions, when, for a few hours, wind and snowdrift rendered it impossible to stand or to see the thermometers outside. Any ordinary gale can be faced if the observer is protected by oilskins, and at night keeps his lantern to leeward of him while he feels his way along the guide-rope stretched from the door to the instrument stands; but when the wind rises above 100 miles per hour, carrying with it drift torn up from the snow lying on the hill-sides, sufficiently solid to break a plate-glass window when dashed against it, it is useless to attempt any out-door observing. A storm of this sort may be expected about every second or third winter, and, in order to secure continuity in the temperature record, arrangements have been made whereby a louvred screen can be placed on the wall of the tower, and the thermometers in it read from within. Experience has shown that this method gives temperature values practically identical with those of the ordinary screens in stormy weather, though on calm and sunny days the thermometers would get unduly heated by the near presence of the tower wall. Under ordinary circumstances, one observer is on duty from 8 p.m. to 4 a.m.; he then wakens the other, who has had this time for sleep, and goes to bed himself; the second observer is on duty till noon, and then both are at work in the afternoon. By this system of work not only are the observations recorded as they go on, but they are reduced, tabulated, averaged, and put in

a form suitable for further investigations by the same persons who take them. Several members of the staff have found time to carry out discussions of the results so obtained, most of which work will be found in the publications of the Royal Society of Edinburgh and of the Scottish Meteorological Society.

Taking an average over the year, the summit of Ben Nevis is in mist for two days out of every three, for only one-third of the time is the hill-top clear. The mist varies much in character: sometimes it is thin, but intensely wetting; at other times it is much thicker, reducing the visible world to a few square yards, but comparatively dry. The wetter forms are classified as mists, and the drier as fogs, but no exact distinction can be drawn, as the degrees of dampness vary insensibly from what soaks worse than heavy rain, because more penetrating, to what seems to render the atmosphere opaque without wetting things exposed to it. As long as the air temperature is above freezing, little inconvenience is caused by either fogs or mists, which are interesting meteorological phenomena, but that is all; in frost, however, they become serious drawbacks to accurate observing, for it is no longer moisture that is deposited upon them, but hard, solid ice out of a mist, and masses of loose, feathery crystals from a fog. These form on the windward side of everything that the air touches, and the fog-crystals in a strong wind and thick fog may grow at the rate of two feet per day, though not a particle of snow be falling. No self-registering instruments that had to be left to themselves for many hours at a time would work under such conditions; it is necessary that personal inspection of the thermometers should be made at least once an hour, the fog-crystals cleared away, or, if necessary, the whole screen removed and another put out. Mist is even a worse enemy in the winter, as the moisture from it turns at once into ice, and frequently rain falls at the same time, freezing as it touches the snow, and rapidly covering everything with a thick layer of hard ice. This ice cannot be knocked off posts, screens, &c., like the fog-crystals, and it adds greatly to the labour of shifting the thermometer screens, and keeping things in order generally. Fortunately, mist is rare, even rarer than fine weather; fog is the normal condition in winter.

The finest weather of the year on Ben Nevis, as in the North-west Highlands generally, is in spring and early summer. From March to June every year there are long spells of dry, sunny weather, such as never occur in autumn, and the observers are

able both to do more outside work and to enjoy the pleasures of tobogganing, snow-shoe tramps, and other semi-arctic sports. The pleasures of flying down the hill-side on a toboggan are heightened by the knowledge that, if guided wrongly, or allowed to run too far, the course may end in a precipice or some such obstacle. But, with fair care, a great amount of good sport can be obtained, the latest addition to the stock of amusements being Norwegian snow-shoes, or "skier," on which the novice learns speedily to slide down hill, but finds it impossible to do anything else, even to stop, without a tumble.

The view on a clear day extends from Ben Wyvis in the north to the coast of Ireland, and from the Outer Hebrides to the Cairngorm Mountains; but a feature of the view is that no town or village of more than two or three houses can be seen, except a few of the outlying buildings of Inverness. Many populous places lie within this range. Fort-William and Oban are quite near; Glasgow, Paisley, Greenock, and Stirling are no further away than the Island of Jura, which is visible any moderately clear day; yet none of these places can be seen, they are all hid by intermediate hills; indeed, the aspect of the country is all hills, the valleys where men live disappear, and nothing can be seen but ridge behind ridge of barren mountains. Almost the only open space in sight is the Moor of Rannoch, that central wilderness of Scotland. But the view is saved from monotony by the abundance of water. The Atlantic Ocean forms the western horizon, and Loch Linnhe, with its broken and winding coast-lines, spreads out from just below the spectator's feet, while every here and there fresh-water lochs and tarns gleam out amongst the hills.

Snow seems to lie on Ben Nevis longer than on any of the other hill-tops near, due, doubtless, to its flatness. The summit is rather an elevated plateau than a ridge or cone, and the snow gets better opportunity to accumulate than on a narrow ridge. Strangers coming up in early summer often express surprise at finding snow lying on a warm day exposed to a blazing sun, and it is difficult to convince them that it is melting away as fast as it can, and that it is only the great quantity which falls in winter that enables it to last so long through weeks of thaw. May is generally the first month in which there is a distinct melting away of the winter snow, and April, therefore, is the month in which it reaches its maximum depth. While the snow is falling

and increasing in depth, the wind drifts it about freely, and the house soon gets banked up all round. Digging out doors and windows is a vain work, for the loose drift settles in every sheltered hollow, and quickly fills up the holes dug out; but, as the winter goes on, the doorway is kept clear by building an archway of snow over the steps up from the ground level to the top of the snow, and thus making a porch, the outer end of which can be closed in stormy weather, and into which, even when open, the snow is not drifted as into a hole unprotected by any cover. As the snow increases, the porch is lengthened, until in some winters it has been fully 30 feet long, with a rise of 12 or 14 feet.

NOTES ON ILLUSTRATIONS.

1. *Summit of Ben Nevis.*—This view shows the highest part of Ben Nevis. It is a winter scene, with the snow lying deep on the summit and clinging to every ledge and crack on the northern cliffs. The tower of the Observatory occupies the highest spot to the right.

2. *The ordinary appearance of the Hill-top in Summer.*—The ground is seen to be covered with loose stones, the disintegrated rock of the hill, without vegetation or soil; the Observatory buildings are in the centre; some of the instrument stands are to the left. The Ordnance Cairn, marking the highest point of the British Isles, is a little to the right, but not included in the view.

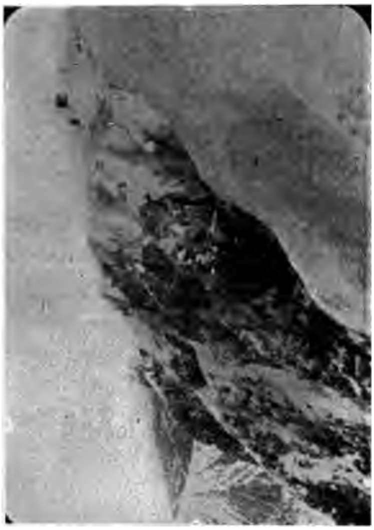
3. *The Observatory in early Spring.*—The snow, lying 10 or 12 feet deep, has buried the main part of the building, leaving only the tower, chimneys, and ventilators visible; but in the front of the picture there is shown the entrance to a snow-built archway which leads down to the doorway, and supplies light and fresh air to one of the principal windows on the way. This porch is carried on bit by bit as the snow deposit increases, and does not readily get drifted up, as a merely open passage would.

4. *The Tower of the Observatory covered with Fog Crystals.*—All these masses of feathery crystals are deposited directly out of fog, and are not snow-flakes. A fog which wets everything when the temperature is above freezing deposits crystals of ice when it is below, and quickly coats the windward side of all bodies exposed to it. The stronger the wind the more rapid the growth; that in the picture was due to a day of strong southerly wind, with thick fog, but no snow.

5. *The Instrument Stands.*—The thermometers and other instruments that it is advisable to keep at a constant height above the surface are shifted step by step up these ladder-like stands as the snow gets deeper.

6. *Winter Costume.*—Oilskin coats, deerskin gloves, sou'-wester hats, long boots, snow shoes, and all the clothing and equipment designed for a wet, a stormy, and an Arctic climate come in useful on Ben Nevis.

"BEN NEVIS" Illustrations.



No. 1.

No. 2.

No. 3.

No. 4.

MACLURE, MACDONALD & CO. LITH.

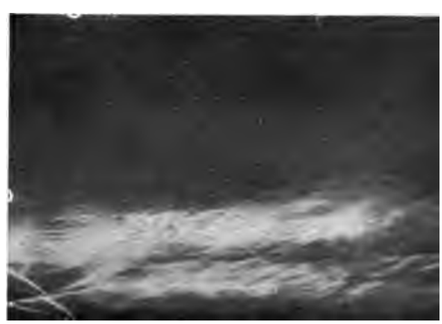
"BEN NEVIS" Illustrations.

No. 5.

No. 6.

No. 8.

No. 7.



No. 9.

7. *Clouds among the Hills.*—The snow-covered foreground is Ben Nevis itself, and the darker masses are the hills to the south of Glen Nevis; but beyond a dense layer of cloud hides all except the highest ridges of the Glencoe and Buchaille Etive Mountains, and a few of the peaks of Argyleshire. In winter clouds of this form sometimes continue for two or three days in succession.

8. *A Cumulus Cloud.*—An interesting point in these photographs is that they can be taken from about the same height as that at which the clouds are floating, thus giving a side view of the cloud, instead of merely its under surface.

9. *Cirrus Cloud.*—The interest in this picture lies in the fact that the photograph was taken at midnight, and represents a cloud near the northern horizon lit up by the sun. This phenomenon is only seen near the summer solstice, when the sun, though invisible, is so little below the horizon at midnight that its rays reach and illuminate high clouds midway between Ben Nevis and the Arctic Circle.

REPORTS OF SECTIONS.

SESSION 1895-96.

[Received at Meeting of Society, 29th April, 1896.]

1. Report of the Architectural Section.

This Section held eight Meetings during the Session, at which the following papers were read :—

Monday, 18*th November*, 1895.—Mr. T. L. Watson, Architect, F.R.I.B.A., President of the Section, delivered his Opening Address, the subject being "Glasgow Cathedral: A Contribution to the History of the Structure."

Monday, 2*nd December*, 1895.—Mr. James H. Craigie, the "Alexander Thomson" Travelling Student, read a paper on "My Student Tour" (with lime-light illustrations).

Monday, 16*th December*, 1895.—Mr. David Hunter, M.I.M.E., Electrical Engineer, read a paper on "Progress in Electric Lighting."

Monday, 20*th January*, 1896.—Mr. James Chalmers, Architect, read a paper on "The Crematoria of Europe and America" (with lime-light illustrations).

Monday, 3*rd January*, 1896.—Mr. Charles Gourlay, I.A., A.R.I.B.A., Professor of Architecture in the Glasgow and West of Scotland Technical College, read a paper on "The Teaching of Architecture in the College."

Monday, 17*th February*, 1896.—Mr. Henry D. Walton, Architect, read a paper on "Modern Church Planning" (with lime-light illustrations).

Monday, 2*nd March*, 1896.—Mr. A. Lindsay Miller, Architect, read a paper on "Photography a Help to the Study of Architecture" (with illustrations of apparatus, methods, &c., and with lantern views).

Monday, 16th March, 1896.—Mr. John Honeyman, Architect, R.S.A., read a paper on "Church Architecture in Scotland during the Present Century" (with lime-light illustrations).

The thanks of the Section are due to those gentlemen.

Ten Associates were elected during the Session.

The Annual Business Meeting was held on Monday, 16th March, 1896. [The gentlemen named on p. 212 were elected to office for Session 1896-97.]

A. Lindsay Miller, Architect,
Hon. Secretary,
122 Wellington Street.

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2. Report of the Geographical and Ethnological Section.

The Secretary has nothing of special interest to report.

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3. Biological Section.

4. Chemical Section.

Both of these Sections are for the present suspended by vote of Council, 26th November, 1890.

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5. Report of the Economic Science Section.

A Business Meeting of the Section was held on 20th November, 1895, at which the Office-Bearers for the year were elected. [Their names appear on p. 213.]

4th December, 1895.—Bailie Samuel Chisholm, Convener of the Improvement Committee of the Trust, read a paper on "The History and Results of the Glasgow City Improvement Trust."

18th December, 1895.—Richard Lodge, M.A., Professor of History in the University of Glasgow, delivered an address on "Why has England become a Great Manufacturing, Commercial, and Colonising Country?"

18th March, 1896.—Miss Margaret H. Irwin, Assistant Commissioner, late Royal Commission on Labour, read a paper on "Women's Industries in Scotland."

Those papers were read at Meetings of the Society as communications from this Section, and discussions followed in each case. Members of the Town Council of Glasgow, the Glasgow

Trades' Council, and some working women were present, by invitation, at Meetings in which they had a special interest.

ROBERT LAMOND,
Hon. Secretary.

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6. REPORT OF THE MATHEMATICAL AND PHYSICAL SECTION.

No Meeting of this Section was held during the Session for the reading of papers, but important communications were made to the Society through the Section, including papers on Röntgen rays by Dr. J. T. Bottomley, Lord Blythswood, and Dr. John Macintyre.

MAGNUS MACLEAN,
Hon. Secretary.

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7. REPORT OF THE SANITARY AND SOCIAL ECONOMY SECTION.

A Meeting of this Section was held on 18th November, 1895, at which the Office-Bearers for 1895-96 were recommended for election by the Society. [Their names are given on p. 212.]

The following papers were read before the Society:—Mr. D. Fulton on "Domestic Hot-Water Distribution and Kitchen Boiler Explosions;" and Mr. James Chalmers, I.A., "A Biographical Notice of the late Mr. W. P. Buchan, Sanitary Engineer."

W. R. M. CHURCH,
Secretary,
104 WEST GEORGE STREET.

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8. REPORT OF THE PHILOLOGICAL SECTION.

The Secretary has to report continued apathy regarding Sectional work, few or no Members taking interest in it. The only paper read before the Society in the past Session was a contribution from the Secretary on "The Influence of Robert Burns on European Literature."

No change is suggested on the list of Office-Bearers.

JAMES COLVILLE,
Hon. Secretary and Treasurer.

P.S.—There is no charge in favour of or against the Section for the Treasurer's consideration.

MINUTES OF SESSION,

1895-96.

6th November, 1895.

The Philosophical Society of Glasgow held its First Meeting for Session 1895-96, in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 6th November, 1895, at Eight o'clock—Professor John Ferguson, LL.D., F.R.S.E., President, in the Chair.

1. The Minutes of Meeting held on 2nd May, 1895, were read and approved of, and signed by the Chairman.

2. The President then proceeded to deliver the Opening Address, which dealt chiefly with a review of the labours of the late Dr. Hermann Kopp, of Heidelberg, as a historian of the Science of Chemistry. On the motion of Professor M'Kendrick, the President was awarded a very hearty vote of thanks for his address.

3. Dr. D. Fraser Harris, Assistant to Professor M'Kendrick in the Physiological Laboratory of the University, exhibited and described a new Optical Instrument, known as the Stereo-photo-chromo-scope, the invention of Mr. Frederick E. Ives, of Philadelphia, the only instrument of the kind on this side of the Atlantic. He was assisted by Mr. Ward, of London, the inventor's agent in this country. Many of the members inspected the instrument, and were much surprised at finding that the flat, colourless, photographic pictures exposed in it appeared in solid relief, and with all their natural colours. Dr. Harris was awarded a very hearty vote of thanks for the exhibition and description of the instrument.

4. Mr. P. Falconer and Mr. Jas. D. Borthwick were appointed Auditors to examine the Treasurer's Accounts for the year 1894-95.

5. The Chairman announced that all the new Candidates for admission into the Society—as follow—had been elected:—

1. Mr. Robert Dunlop Cassells, B.Sc., Engineer, 62 Glencairn Drive, Pollokshields. Recommended by Professor Archibald Barr, Dr. J. T. Bottomley, and Dr. Magnus Maclean.
2. Mr. G. R. Thompson, Lecturer on Geology and Mining, Glasgow and West of Scotland Technical College. Recommended by Professor A. H. Sexton, Mr. L. H. Cooke, and Professor W. H. Watkinson.
3. Mr. William Henry Houstoun, Cashier, Hill Crest, Cambridge Drive, Glasgow. Recommended by Mr. John F. Campbell, Mr. John Mann, and Mr. J. M'Kellar.
4. Mr. William C. M'Bain, Factor, 75 Jamaica Street. Recommended by Mr. Thomas S. Cree, Mr. John Mann, and Mr. George Barclay.
5. Mr. Charles R. Gibson, Manufacturer, St. Mirren's Mills, Paisley. Recommended by Mr. John Mann, Mr. John Mayer, and Mr. John Mann, Jun.

20th November, 1895.

The Annual General Meeting of the Philosophical Society of Glasgow was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 20th November, 1895, at Eight o'clock—Professor John Ferguson, LL.D, F.R.S.E., President, in the Chair.

1. The Minutes of the First Ordinary General Meeting for Session 1895-96, which were printed in the Billet calling the Meeting were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, elected on 6th November, were admitted to the Membership of the Society:—

1. Mr. Robert Dunlop Cassells, B.Sc., Engineer, 62 Glencairn Drive, Pollokshields.
2. Mr. G. R. Thompson, Lecturer on Geology and Mining, Glasgow and West of Scotland Technical College.
3. Mr. William Henry Houstoun, Cashier, Hill Crest, Cambridge Drive, Glasgow.
4. Mr. William C. M'Bain, Factor, 75 Jamaica Street.
5. Mr. Charles R. Gibson, Manufacturer, St. Mirren's Mills, Paisley.

3. The Annual Report by the Council on the State of the Society, having been printed in the Billet convening the Meeting,

was held as read. Its adoption was moved from the Chair, and unanimously agreed to. The Report was as follows:—

Report of Council for Session 1894-95.

I. *Meetings.*—The last Session of the Society opened on 7th November, 1894, when Professor Ferguson, LL.D., President, delivered an address dealing chiefly with "Recent Contributions to the Literature of Gold-making." Fourteen meetings were held during the Session, one of which, an extra meeting, was held in the Natural Philosophy Class-Room at the University, on the evening of Wednesday, 27th March, when Lord Kelvin made two important communications to the Society. Including the President's Opening Address, twenty-two communications were submitted to the Society in the course of the Session.

II. *Membership.*—At the beginning of the Session there were 629 Ordinary Members on the Roll. In course of the Session 28 candidates were elected, making 657. Of these, 19 have resigned, 10 have died, 5 have left Glasgow, and their names have been placed on the "Suspense List," and 3 have been struck off the Roll for non-payment of subscriptions, so that, at the beginning of 1895-96, there were 619 Members, being a decrease of 9. Of the new Members admitted during the Session 3 qualified themselves as Life Members. There are now 138 Members of that class out of the 149 who had so enrolled themselves. In the List of Honorary Members, the number of whom is limited to 20, there are 8 vacancies, so that the Roll now includes 12 Honorary Members, 3 being Continental, 3 American or Colonial, and 6 British. The number of Corresponding Members remains at 10, as it was last year. The Membership of the Society, then, is as follows:—Honorary Members, 12; Corresponding Members, 10; Ordinary Members (Annual and Life), 620; or a total of 642. No Ordinary Members who took a prominent position in the work of the Society have been removed from the roll by death during the year, but in the list of Honorary Members three notable blanks have been made. Professor Dana, the eminent geologist and mineralogist of the United States; Professor T. H. Huxley, Past-President of the Royal Society, and one of the most distinguished scientific men of the present century; and Louis Pasteur, of Paris, great alike as a chemist and as a bacteriologist,—are now all numbered with the dead. Dana was elected an Honorary Member of the Society in 1860, Huxley in 1876, and the great French *savant* in 1885.

III. *Sections.*—The Session of the *Architectural Section* included eight meetings, the first of which, held on 9th November, 1894, took the form of a conversazione, which was largely attended by members and their lady friends. One of the papers provided by this Section was read at a joint-meeting of the Section with the Society on 6th March, 1895, the author being Colonel R. W. Edis, F.S.A., Architect, London, who discoursed on "Internal Arrangements and Decorative Treatment of Town Houses." An abstract of the Opening Address of the President (Mr. T. L. Watson), which dealt with "Four Great Periods of Italian Art," is given in the new Volume of the Society's *Proceedings*, in which there is also contained

another paper from the same Section. The *Geographical and Ethnological Section* held five meetings, under the arrangement between the Society and the Royal Scottish Geographical Society. The other Sections all provided communications, which were read at ordinary meetings of the Society.

IV. *Proceedings, Volume XXVI.*—This Volume of the *Proceedings*, now n the hands of the Members, contains sixteen papers—one of them in abstract,—several of them being illustrated. It is specially worthy of note that the Volume, now for the first time, is bound in cloth. This improvement has involved some additional expense, but the Council feel satisfied that it will be appreciated by the Members generally.

V. *Special Lectures.*—The Council are glad to be able to state that they have concluded arrangements for the delivery of a "Graham" Lecture, on the 8th January, 1896, the lecturer being Professor William Ramsay, Ph.D., F.R.S., of University College, London, who, along with Lord Rayleigh, the discoverer of the new chemical element Argon, carried out an elaborate course of investigation regarding that substance as well as on Helium, the other new element. The lecture will deal with the discovery, distribution, and properties of those chemical elements. A lecture on "The Ben Nevis Observatories and their Work" will also be given on 19th February, 1896, in connection with the Glasgow Science Lectures Association Trust, whose funds are now administered by the Council of the Philosophical Society. It will be given jointly by Mr. Omond, Superintendent of the Observatories, and Dr. Alexander Buchan, M.A., F.R.S.E., Secretary of the Scottish Meteorological Society.

VI. *Congratulatory Address to the Institute of France.*—As the centenary of the Institute of France occurred this year, an Address of Congratulation was drawn up by the President and Secretary of the Society, and forwarded to the Institute, on the occasion of the celebration of the event in October. Lord Kelvin, the Senior Honorary Vice-President of this Society, and one of the Eight Foreign Associates of the Academy of Sciences, attended the Centenary celebration as representing the Royal Society, of which he is President, a fact which lends special interest to the Address from the Philosophical Society.

VII. *Electric Lighting of Hall.*—Since the close of Session 1894-95, the House Committee, acting on behalf of the Society and the Institution of Engineers and Shipbuilders, the joint-owners of the premises at 207 Bath Street, have had the Large Hall fitted up with an Electric Light Installation, which has already given much satisfaction to the Members.

VIII. *Finance.*—The Treasurer's Statement opens with a balance of cash on hand of £2 17s. 6½d., to which add the investment mentioned in last Report, £294 18s. 3d., making £297 15s. 9½d. The accounts close with a balance of £30 in bank, less £1 18s. 6½d. due to Treasurer, making, with above investment, £322 19s. 8½d., so that there has been an increase during the year of £25 3s. 11d. All current indebtedness to the closing date of

financial year is believed to have been paid, except the cost of the Electric Light Installation, which properly belongs to the new Session.

By order and in name of the Council.

(Signed) JOHN MAYER,
Secretary.

4. The Treasurer's audited Statement of the Funds of the Society, which had also been printed in the Billet, was next submitted by the Chairman, and its adoption was unanimously approved of. The Abstract of Treasurer's Account of the Graham Medal and Lecture Fund, and that of the Science Lectures Association Fund, were also submitted and approved of. These Statements, signed by the Auditors, were laid on the table. [They are given on pp. 196-199.]

5. Mr. John Robertson, on behalf of the Library Committee, submitted the Report on the State of the Library. Its adoption was agreed to, and, on the motion of Mr. Robertson, the thanks of the Society were awarded to the donors of Books to the Library during the year. The following is the Report:—

Report of the Library Committee.

The Library Committee have to report that during the past year 58 volumes and 13 parts of works were added by purchase, many of these on the recommendation of Members, while 15 volumes, 15 parts of works, and 27 pamphlets were presented.

The Society's *Proceedings* were forwarded to 179 Societies and public departments, and 119 volumes and 19 parts of works were received in exchange.

The periodicals received at the Library number 99, of which 69 are bought and 30 are presented. These form in all 102 volumes annually.

Altogether there have been added to the Library, since last report, 294 volumes, 105 parts of works, and 27 pamphlets, making an estimated total of 12,223 volumes.

In addition to works consulted in the Library, 748 volumes were issued to 507 members.

The number of volumes bound during the year was 193.

The following societies were added by request to the list of exchanges—L'Academie Imperiale des Sciences de St. Pétersbourg, the Royal University of Upsala, La Faculté des Sciences de Marseille, the Society of Physical Science of Bucharest, the Portland Society of Natural History (Maine), and la Société Scientifique du Chili.

Dr. ABSTRACT OF HONORARY TREASURER'S
AND COMPARISON WITH

			1894-95.	*1893-94.*
To BALANCE from last year—				
In Treasurer's hands, ...		. £2 17 6½		
Investment, Caledonian Railway, .		. 294 18 3	£297 15 9½	*£271 12 6½*
,, SUBSCRIPTIONS to 31st October, 1895—				
2 Entry-moneys of 1893-94 at 21s., ...	£2 2 0			
28 Entry-moneys of 1894-95 at 21s., ...	29 8 0			
1 Entry-money of 1895-96 at 21s., ...	1 1 0			
		£32 11 0		*30 9 0*
Annual Dues at 21s.—				
Arrears, ...	£4 4 0			
For 1894-95, 436 Ordinary Members, ...	457 16 0			
,, ,, 28 New Members,	29 8 0			
		491 8 0		*510 6 0*
Life Subscriptions at £10 10s.—				
4 Old Members, ...	£42 0 0			
3 New Members, ...	31 10 0			
		73 10 0		*42 0 0*
			597 9 0	
,, DIVIDENDS ON INVESTMENT—				
Caledonian Railway, April, 1895, less tax,		£5 4 5		
,, ,, Oct., ,, ,,		5 4 5		
			10 8 10	*10 9 5*
,, GENERAL RECEIPTS—				
Bank Interest, ...		. £1 6 6		*2 7 1*
Proceedings and Catalogues sold, . . .		. 2 12 9		*0 17 0*
			3 19 3	
,, LEGACY by the late Sir Michael Connal—				
Second instalment, less duty, ...			1 2 6	*2 5 0*
,, ARCHITECTURAL SECTION—				
86 Associates' fees for 1894-95, at 5s., . . .			21 10 0	*22 10 0*
,, ECONOMIC SCIENCE SECTION—				
16 Associates' fees for 1894-95, at 5s., . . .			4 0 0	*4 0 0*
,, GEOGRAPHICAL AND ETHNOLOGICAL SECTION—				
Associates' fees, ...			4 0 0	*0 0 0*
			£940 5 4½	*£896 16 0½*

Memo. by Treasurer.—The Society's Investments are—(1) Bath Street Joint Buildings, as in last Account, ... £3,547 8 1½
whereof, Paid from Society's Funds, ... £2,047 8 1½
Do. Society's half of £3,000 Bond, . 1,500 0 0
(2) Caledonian Railway Stock, as in foregoing Account, . . 294 18 3

£3,842 6 4½

J. M.

ACCOUNT—SESSION 1894-95, **Cr.**
SESSION 1893-94.

		1894-95.	*1893-94.*
By GENERAL EXPENDITURE to 31st October, 1894—			
Salary to Secretary, ...	£75 0 0		*£75 0 0*
Allowance for Treasurer's Clerks, . . .	15 0 0		*15 0 0*
		£90 0 0	
New Books & Periodicals, British & Foreign,	£110 13 9		*111 12 6½*
Bookbinding, ...	19 18 0		*15 15 2*
Printing Circulars, *Proceedings*, &c., .	162 0 0		*148 12 0*
Lithographs, &c., for *Proceedings*, &c., . .	12 6 0		*19 5 0*
Postage and delivery of Circulars, Letters, &c.,	32 0 5		*35 15 10*
Stationery, &c., ...	2 8 6		*3 11 11*
	£339 6 8		
Less—Contribution towards Illustration, .	4 10 0		
		334 16 8	
Fire Insurance on Library for £5,400, . .	£6 2 9		*6 1 3*
Postages, &c., per Secretary, £2; per Treasurer, £2 16s. 10½d., & Sundries, 6s. 8d., .	5 3 6½		*4 17 10*
		11 6 3½	
,, Joint Expenses of Rooms—Society's half of £374 16s. 5d., being Interest on Bond, Insurance, Taxes, Cleaning, Repairs, Lighting, and Heating; Salaries of Curator and Assistant, less half of £59 14s., Revenue from Letting, ...		157 11 2½	*136 7 4*
,, LECTURE EXPENSES—			
Scottish Geographical Society, Rent for five Joint Lectures, ...	£5 0 0		*4 5 0*
Advertising, 18s. 10d.; Sundries, 2s., . .	1 0 10		*1 7 2*
		6 0 10	
,, SUBSCRIPTIONS TO SOCIETIES—			
Ray Society, 1894, ...	£1 1 0		*1 1 0*
Palæontographical Society, 1894, . .	1 1 0		*1 1 0*
		2 2 0	
,, ARCHITECTURAL SECTION—			
Expenses per Treasurer of Section, ...		10 17 7	*13 16 9*
,, ECONOMIC SCIENCE SECTION—			
Expenses per Treasurer of Section, . .	£0 5 8		*3 10 5½*
Printing Account, ...	0 0 0		*2 0 0*
		0 5 8	
,, GEOGRAPHICAL AND ETHNOLOGICAL SECTION—			
Expenses per Treasurer of Section, . .	£1 12 2		*0 0 0*
Printing Account, ...	2 13 3		*0 0 0*
		4 5 5	
,, BALANCES, viz. :—			
Investment—Caledonian Railway £360 3 per cent. Preferred Converted, and Expenses,	£294 18 3		*294 18 3*
In Clydesdale Bank, . £30 0 0			*0 0 0*
Less—Due Treasurer, . 1 18 6½	28 1 5½		*2 17 6½*
		322 19 8½	
		£940 5 4½	*£896 16 0½*

GLASGOW, *15th November, 1895.*—We, the Auditors appointed by the Society to examine the Treasurer's Accounts for the year 1894-95, have examined the same, of which the above is an Abstract, and have found them correct, the Balance due Treasurer being One Pound Eighteen Shillings and Sixpence-halfpenny.

(Signed) PATRICK FALCONER.
JAS. D. BORTHWICK.

JNO. MANN, C.A., *Honorary Treasurer.*

GRAHAM MEDAL AND LECTURE FUND.

Dr. ABSTRACT OF TREASURER'S ACCOUNT—SESSION 1894-95. Cr.

Dr.			Cr.		
CAPITAL AT 1ST NOVEMBER, 1894—			CAPITAL AT 31ST OCTOBER, 1895—		
Glasgow and South-Western Railway Co. 4 % Preference Stock in name of the Philosophical Society, in Trust,	£250 0 0		Investment, *per contra*,	£250 0 0	
Value of Die at H.M. Mint,	18 18 0		Die,	18 18 0	
		£268 18 0			£268 18 0
Cash in Bank,		44 2 7	BALANCE, BEING REVENUE—		
REVENUE—			In Bank, on Deposit Receipts,		54 5 9
Dividend, April, 1895, less Tax,	£4 16 8				
" Oct. " "	4 16 8				
Interest from Bank,	0 9 10				
		10 3 2			
		£323 3 9			£323 3 9

GLASGOW, 15th November, 1895.—Examined and found correct.

(Signed) PATRICK FALCONER.
JAS. D. BORTHWICK.

JNO. MANN, C.A., *Treasurer.*

THE SCIENCE LECTURES ASSOCIATION FUND.

Dr. ABSTRACT OF TREASURER'S ACCOUNT—SESSION 1894-95. Cr.

Dr.

CAPITAL AT 1ST NOVEMBER, 1894—		
£200 Caledonian Railway Company 4°/o Preference Stock, No. 1, in name of the Philosophical Society, in Trust, cost - - - - - - - -	£244 4 8	
On Deposit Receipt, - - - - -	8 5 4	
		£252 10 0
Cash in Bank (Revenue), - - - - - -		41 11 1
REVENUE—		
Dividend, April, 1895, less Tax, - -	£3 17 4	
,, Oct., ,, ,, - -	3 17 4	
Interest from Bank, - - - - -	0 10 7	
		8 5 3
		£302 6 4

Cr.

CAPITAL AT 31ST OCTOBER, 1895—		
Investment, *per contra*, - -	£244 4 8	
In Bank on Deposit Receipt, -	8 5 4	
		£252 10 0
BALANCE, BEING REVENUE—		
In Bank, on Deposit Receipts, - - - - -		49 16 4
		£302 6 4

GLASGOW, 15th November, 1895.—Examined and found correct.

(Signed) PATRICK FALCONER.
JAS. D. BORTHWICK.

JNO. MANN, C.A., *Treasurer*.

In Volume XXVI. of the *Proceedings*, pp. 274-275, there will be found a list of all the additions to the Library by purchase, up to June, 1895; the titles of the books presented, with the names of the donors, the names of the societies, public departments, &c., with which exchanges are effected, and a list of the periodicals received at the Library.

The space for the accommodation of books has been for some time ex hausted, but the House Committee took possession, in May last, of the Curator's house, which will now be available for Library purposes.

JOHN ROBERTSON, LIBRARIAN,
Convener.

6. The Society then proceeded to the election of Office-Bearers:—

(1) On the recommendation of the Council, and on the motion of the Chairman, seconded by Mr. W. P. Buchan, Dr. Eben. Duncan was elected President of the Society in succession to Professor Ferguson. Dr. Duncan then took the chair, and thanked the Society for placing him in such an honourable position. On his motion a very hearty vote of thanks was passed to Professor Ferguson, the retiring President, who briefly replied.

(2) On the motion of the President, Mr. F. T. Barrett, recommended by the Council, was elected Vice-President of the Society in room of Mr. Lang, whose term of office had expired; and Mr. Gilbert Thomson, M.A., C.E., was elected Vice-President for the unexpired two years of Dr. Duncan's term.

(3) On the motion of the Chairman, Messrs. Mann, Robertson, and Mayer were re-elected Treasurer, Librarian, and Secretary, respectively.

(4) The vacancies in the Council were filled up by the election of Mr. William Lang, Dr. Freeland Fergus, Dr. Magnus Maclean, and Mr. J. Craig Annan, in room of four Members whose term of office had expired.

(5) The appointment of Office-Bearers of the Geographical and Ethnological, Sanitary and Social Economy, Mathematical and Physical, Economic Science, and Philological Sections, subsequently took place, in accordance with resolutions of the Society of 11th April, 1883, 18th November, 1885, and 2nd February, 1887. [The Lists of the Office-Bearers of the Society and of the various Sections are given on pp. 210-213.]

7. Dr. Joseph Coats, Professor of Pathology in the University of Glasgow, read a paper on "Immunity to Infectious Diseases: a Pathological Study in view of Recent Researches." In the discussion to which it gave rise, Dr. John Dougall, Dr. Glaister, Dr. Freeland Fergus, Professor Marshall, and the President took part. Dr. Coats briefly replied, and was awarded a cordial vote of thanks for his paper.

The Chairman announced the unanimous election of the candidates who had been balloted for, namely :—

1. Mr. Robert Turnbull, Architect, 122 Wellington Street. Recommended by Mr. T. L. Watson, Mr. A. Lindsay Miller, and Mr. John Mayer.

2. Mr. David Sclanders, Jun., Merchant, 71 Waterloo Street. Recommended by Dr. William Smart, Mr. John Mann, and Councillor Maclay.

3. Mr. J. B. Mackenzie Anderson, M.B., 42 Lansdowne Crescent. Recommended by Dr. Freeland Fergus, Mr. John Mann, and Mr. John Mayer.

4th December, 1895.

The Second Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 4th December, 1895, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Annual General Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, who were elected on 20th November, were admitted to the Membership of the Society :—

1. Mr. Robert Turnbull, Architect, 122 Wellington Street.
2. Mr. David Sclanders, Jun., Merchant, 71 Waterloo Street.
3. Mr. J. B. Mackenzie Anderson, M.B., 42 Lansdowne Crescent.

3. A paper on "The History and Results of the Glasgow City Improvement Trust" was read by Bailie Samuel Chisholm, Convener of the Improvement Committee. It was very favourably received by the meeting, and at the close a discussion took place, in which the speakers were Dr. Smart, Mr. James Chalmers, Bailie M'Phun, ex-Councillor Scott, Mr. Sloan, Mr. H. A. Mavor, Mr. M. Gass, and the Chairman. Bailie Chisholm made a brief reply, and was awarded a very hearty vote of thanks for his valuable communication.

4. The Chairman announced that the following Candidates for admission into the Society had all been elected :—

HONORARY MEMBERS.

1. Sir JOSEPH LISTER, Bart., LL.D., D.C.L., President of the Royal Society, and formerly Professor of Surgery in the University of Glasgow.
2. Sir ARCHIBALD GEIKIE, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of Great Britain and Ireland.
3. Professor S. P. LANGLEY, LL.D., D.C.L., Secretary of the Smithsonian Institution, Washington, U.S.A.

ORDINARY MEMBERS.

1. Mr. DAVID STRATHIE, C.A., 162 St. Vincent Street. Recommended by Mr. William Wallace, Mr. John Mann, Jun., and Mr. T. A. Craig.
2. Mr. JAMES F. MARTIN, Leather Merchant, 63 Brunswick Street. Recommended by Dr. William Smart, Mr. Robert Lamond, and Mr. John Mann.
3. Professor RICHARD LODGE, M.A., The University. Recommended by Dr. William Smart, Mr. John Mann, and Professor Ferguson.
4. Mr. WILLIAM B. SMITH, Silversmith, 31 Queen Street. Recommended by Mr. William Wallace, Mr. John Robertson, and Mr. William Lang.

18th December, 1895.

The Third Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 18th December, 1895, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Second Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, who were elected on 4th December, were admitted to the Membership of the Society :—

1. Mr. DAVID STRATHIE, C.A., 162 St. Vincent Street.
2. Mr. JAMES F. MARTIN, Leather Merchant, 63 Brunswick Street.
3. Professor RICHARD LODGE, M.A., The University.
4. Mr. WILLIAM B. SMITH, Silversmith, 31 Queen Street.
5. As also Mr. ROBERT M'LAURIN, Analytical Chemist, who was elected at the closing meeting of last Session on the recommendation of Mr. James Napier, Mr. T. F. Barbour, and Prof. Blyth.

3. Dr. T. F. Tannahill, D.P.H.(Camb.), read a paper on "Pre-historic Man: his Burial Places and his Weapons," which was illustrated by an extensive series of Flint Implements, &c., collected by the author while residing in various parts of the kingdom. A very cordial vote of thanks was passed to Dr. Tannahill for his paper and for the exhibition of his specimens.

4. Prof. Richard Lodge, M.A., of the University of Glasgow, read a paper in answer to the question "Why has England become a Great Manufacturing, Commercial, and Colonising Country?" A discussion ensued, in which the speakers were Dr. Colville, Mr. W. C. M'Bain, and the Chairman, on whose motion Prof. Lodge was very heartily thanked for his paper.

5. The Chairman announced that the following new Candidates for admission into the Society had been elected:—

1. Mr. Sinclair Couper, Engineer, Moore Park Works, Helen Street, Govan. Recommended by Mr. Henry A. Mavor, Mr. John Mann, and Mr. Mayer.
2. Mr. John C. M'Kellar, Architect, 112 Bath Street. Recommended by Mr. J. M'Kellar, Mr. John F. Campbell, and Mr. John Mann.
3. Mr. David Dreghorn, Soap Manufacturer, Smith Street, Kinning Park. Recommended by Sir John Cuthbertson, Mr. Daniel Munro, and Mr. John Mann.
4. Mr. David Lamb, 3 Albion Place, Dowanhill. Recommended by Mr. John Mann, Mr. F. T. Barrett, and Mr. H. A. Mavor.
5. Mr. J. H. Mathieson, 3 Grosvenor Terrace, Kelvinside. Recommended by Dr. Freeland Fergus, Mr. William Lang, and Mr. Mavor.
6. Councillor Robert Anderson, Painter, 76 Bath Street. Recommended by Dr. Eben. Duncan, Mr. Mann, and Mr. Mayer.

8th January, 1896.

The Fourth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 8th January, 1896, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Third Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, who were elected on 18th December, were admitted to the Membership of the Society:—

1. Mr. SINCLAIR COUPER, Engineer, Moore Park Boiler Works, Helen Street, Govan.
2. Mr. JOHN C. M'KELLAR, Architect, 112 Bath Street.
3. Mr. DAVID DREGHORN, Soap Manufacturer, Smith Street, Kinning Park.
4. Mr. DAVID LAMB, 3 Albion Place, Dowanhill.
5. Mr. J. H. MATHIESON, 3 Grosvenor Terrace, Kelvinside.
6. Councillor ROBERT ANDERSON, Painter, 76 Bath Street.

3. Professor William Ramsay, F.R.S., of University College, London, and a former Member of the Philosophical Society of Glasgow, delivered the Triennial "Graham" Lecture, the subject of which was "Argon and Helium." It was listened to with rapt attention by such a large audience as to tax the capacity of the Lecture Hall to its utmost. At the close, on the motion of Professor Ferguson, a very cordial vote of thanks was awarded to the lecturer, who briefly replied.

4. The Chairman announced that the Candidates balloted for had all been elected to the Membership of the Society, as follow:—

1. Mr. ALEXANDER BROWN, The Craigs, Carmunnock. Recommended by Mr. J. T. Costigane, J.P., Mr. John Mann, and Mr. Mayer.
2. Mr. GEORGE DOWIE, Engineer, 101 St. Vincent Street. Recommended by Councillor Cassells, Mr. H. A. Mavor, and Dr. Freeland Fergus.
3. Mr. SAMUEL M'CALL FRAZER, Pharmaceutical Chemist, 127 Buchanan Street. Recommended by Dr. Freeland Fergus, Prof. Ferguson, and Dr. William Smart.

22nd January, 1896.

The Fifth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 22nd January, 1896, at Eight o'clock—Mr. Gilbert Thomson, M.A., C.E., Vice-President, in the Chair.

1. The Minutes of the Fourth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, who were elected on 8th January, were admitted to the Membership of the Society:—

1. Mr. Alexander Brown, The Craigs, Carmunnock.
2. Mr. George Dowie, Engineer, 101 St. Vincent Street.
3. Mr. Samuel M'Call Frazer, Pharmaceutical Chemist, 127 Buchanan Street.

3. Mr. Lewes R. Crosskey, Director of the Department of Industrial Art in the Glasgow and West of Scotland Technical College, read a paper on "Trade Classes and their Importance to the Community." An interesting and important discussion ensued. Colonel R. A. Bennett, and Messrs. M'Culloch and Carlton, all master painters; Professor A. H. Sexton, Mr. Robert Blackie, and Mr. Carter, lithographer; together with several artisans representing the lithographing, printing, and furniture trades. Mr. Crosskey made a brief reply, and was awarded a very hearty vote of thanks for his Paper.

4. The Chairman announced that Mr. John Macdonald, Manufacturing Chemist, 72 Great Clyde Street—recommended by Mr. James Deas, Mr. Gilbert Thomson, and Mr. Mayer,—had been elected to the Membership of the Society.

5th February, 1896.

The Sixth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 5th February, 1896, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Fifth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Mr. John Macdonald, Manufacturing Chemist, 72 Great Clyde Street, who was elected on 22nd January, was admitted to the Membership of the Society.

3. Dr. J. T. Bottomley, F.R.S., Lord Blythswood, and Dr. John Macintyre, severally made communications to the Society on

Röntgen's discovery of "New Photographic Rays," which were extensively illustrated by Lantern Views of objects that had been exposed under cover and over sensitive plates. Professor Blyth also related his experience by the use of an electric arc lamp. Very cordial votes of thanks were passed to Lord Blythswood and Drs. Bottomley and Macintyre.

4. The paper announced on behalf of Mr. John Wilson—"My Experiences on Lake Titicaca"—was postponed till 4th March.

19th February, 1896.

The Seventh Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 19th February, 1896, at Eight o'clock—Mr. Gilbert Thomson, M.A., C.E., Vice-President, in the Chair.

1. The Minutes of the Sixth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman. By arrangement with the Council of the Society, as Trustees of the Fund left by the late Glasgow Science Lectures Association, a joint-lecture was delivered on "The Ben Nevis Observatories and their Work," by Dr. Alexander Buchan, M.A., F.R.S.E., Secretary of the Scottish Meteorological Society, and Mr. R. T. Omond, F.R.S.E., Superintendent of the Observatories. The last-named gentleman showed on the screen and described a large number of views of both observing stations and of the top of Ben Nevis under various seasonal conditions. At the close some remarks were made on the subject of the lecture by Messrs. Falconer, Sayers, Sam. Mavor, and the Chairman; and a very cordial vote of thanks was awarded to Dr. Buchan and Mr. Omond for their interesting lecture.

4th March, 1896.

The Eighth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 4th March, 1896, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Seventh Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Mr. John Wilson, Engineer (late of Dumbarton), read a paper entitled "My Experiences on Lake Titicaca, Peru," in which he gave an account of the transmission of a Steamer of 550 tons (built at Leven Shipyard, Dumbarton) from the Coast of Peru, up the Andes, 13,000 feet, to Lake Titicaca, and its reconstruction there. The paper was illustrated by numerous Lime-light Views. The President moved a vote of thanks to Mr. Wilson for his interesting paper, and the motion was seconded, in a few complimentary remarks, by Mr. J. C. Rogers, Chilian Vice-Consul, who was long resident in South America. The motion was heartily agreed to.

3. Dr. Freeland Fergus subsequently gave a short verbal account of "A Holiday Trip to Iceland and the Faroe Islands," which was also extensively illustrated by Lime-light Views. A cordial vote of thanks was given to Dr. Fergus for his communication.

18th March, 1896.

The Ninth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 18th March, 1896, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Eighth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Miss Margaret H. Irwin, Assistant Commissioner late Royal Commission on Labour, read a paper on "Women's Industries in Scotland." (*A communication from the Economic Science Section.*) A discussion took place, in which the speakers were Dr. William Smart, Mrs. Rutherford, Mr. James Chalmers, Mr. Ballantyne, Factory Inspector; Mr. Robert MacLehose, Printer; Mr. H. A. Mavor, Mr. Galloway, Member of Trades' Council; Mr. Alexander Scott, and the Chairman. A hearty vote of thanks was passed to Miss Irwin for her paper, and she briefly replied on the discussion.

3. Professor Sexton's paper, which was announced in the Billet, was postponed till next meeting of the Society.

1st April, 1896.

The Tenth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 1st April, 1896, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Ninth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Prof. A. H. Sexton, President of the West of Scotland Iron and Steel Institute, read an interesting paper on "The By-Products of the Blast Furnace," which was extensively illustrated by specimens and by diagrams, &c. On the motion of the Chairman, he was awarded the best thanks of the Society for his paper.

3. Mr. David Fulton, Lecturer on Plumbing in the Technical College, read a paper dealing with "Domestic Hot-water Distribution and Kitchen Boiler Explosions." In the discussion which was excited by the paper, remarks were made by Mr. James Murrie, Dr. Glaister, President of the Sanitary Section, and Mr. James Chalmers. Mr. Fulton briefly replied, and was awarded a hearty vote of thanks.

15th April, 1896.

The Eleventh Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 15th April, 1896 at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Tenth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Mr. W. B. Sayers, M.Inst.E.E., Consulting Engineer and Electrician, made a communication to the Society on "Domestic Applications of Electricity," including Heating, Ventilating, and Cooking, all of which were illustrated by experimental demonstrations with the most recent apparatus. Some remarks were made on the subject of the communication, or questions asked, by Mr. Lang, Mr. J. F. Campbell, Mr. James Chalmers, Mr. Sam. Mavor, and Mr. Barrett; and a very hearty vote of thanks was accorded to Mr. Sayers for his interesting demonstration.

3. A Biographical Notice of the late Mr. W. P. Buchan, Sanitary Engineer, was read by Mr. James Chalmers, I.A., Past-President of the Sanitary Section. The Chairman briefly spoke of Mr. Buchan, and, on his motion, Mr. Chalmers was cordially thanked for his paper.

29th April, 1896.

The Twelfth Ordinary and Closing Meeting of the Philosophical Society of Glasgow, for Session 1895-96, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 29th April, 1896, at Eight o'clock—Dr. Eben. Duncan, President, in the Chair.

1. The Minutes of the Eleventh Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Dr. James Colville, M.A., read a paper on "The Influence of Burns on European Literature." (*A communication from the Philological Section.*) A discussion ensued, in which the speakers were Mr. Craibe Angus and Mr. Campbell Douglas. Dr. Colville briefly replied on the discussion, and was awarded a hearty vote of thanks for his interesting paper.

3. The Secretary submitted the Annual Reports from Secretaries of Sections, and was authorised to insert them in the next volume of the Society's *Proceedings.*

4. The President then brought the Session to a close.

OFFICE-BEARERS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

SESSION 1895-96.

President.

EBEN. DUNCAN, M.D., C.M., F.F.P.S.G.

Vice-Presidents.

*DR. JOSEPH COATS.
MR. GILBERT THOMSON, M.A., C.E.
MR. F. T. BARRETT.

Honorary Vice-Presidents.

PROFESSOR THE RIGHT HON. LORD KELVIN, M.A., LL.D., D.C.L., Pres. R.S., Foreign Associate of the Institute of France, Hon. Vice-President R.S.E., and Member of the Prussian Order *Pour le Mérite.*
JAMES B. RUSSELL, B.A., LL.D., M.D.
PROFESSOR JOHN GRAY M'KENDRICK, M.D., LL.D., F.R.S., F.R.S.E., F.R.C.P.E.
PROFESSOR JOHN FERGUSON, M.A., LL.D., F.R.S.E., F.C.S., F.S.A., F.S.A.Scot.

MR. JOHN ROBERTSON, *Librarian.*
MR. JOHN MANN, C.A., *Treasurer.*
MR. JOHN MAYER, *Secretary.*

Presidents of Sections.

MR. T. L. WATSON, Architect, F.R.I.B.A., *Architectural Section.*
DR. JOHN GLAISTER, F.F.P.S.G., D.P.H.(Camb.), *Sanitary and Social Economy Section.*
GEORGE A. TURNER, M.D., *Geographical and Ethnological Section.*
LORD KELVIN, Pres. R.S., &c., *Mathematical and Physical Section.*
WILLIAM SMART, M.A., LL.D., *Economic Science Section.*
DAVID ROSS, M.A., B.Sc., LL.D., *Philological Section.*

Other Members of Council.

*EX-BAILIE WALLACE.
*PROF. BARR, C.E., D.Sc.
*MR. H. A. MAVOR, M.I.E.E.
*MR. A. SOMERVILLE, B.Sc., F.L.S.
DR. JOHN GLAISTER.
PROF. A. H. SEXTON.
MR. A. L. MILLER.
MR. ALEX. SCOTT.
MR. WM. LANG, F.C.S.
DR. FREELAND FERGUS.
Dr. MAGNUS MACLEAN, M.A., F.R.S.E.
Mr. J. CRAIG ANNAN.

* *Retire by rotation in November, 1896.*

COMMITTEES APPOINTED BY THE COUNCIL.

COMMITTEE ON FINANCE.

MR. WILLIAM LANG.
MR. H. A. MAVOR.
MR. A. L. MILLER.
MR. ALEXANDER SCOTT.

MR. JOHN MANN, *Treasurer, Convener.*

MR. LANG, *Sub-Convener.*

COMMITTEE ON THE LIBRARY.

DR. EBEN. DUNCAN, *President.*

DR. COATS, }
MR. BARRETT. } *Vice-Presidents.*

PROF. A. H. SEXTON.
MR. T. L. WATSON.
DR. SMART.
DR. M. MACLEAN.
DR. GLAISTER.
DR. TURNER.
MR. G. THOMSON.
DR. F. FERGUS.
MR. J. C. ANNAN.
MR. LANG.

MR. JOHN ROBERTSON, *Librarian, Convener.*

"SCIENCE LECTURES" TRUST COMMITTEE.

DR. E. DUNCAN, *President.*

DR. M'KENDRICK.
MR. BARRETT.
MR. JOHN MAYER.
DR. COATS.

DR. E. DUNCAN, *Convener.*

HOUSE COMMITTEE.

Consisting of Members of the Philosophical Society and of the Institution of Engineers and Shipbuilders.

Institution of Engineers and Shipbuilders.	*Philosophical Society.*
SIR WM. ARROL, LL.D., M.P.	MR. LANG.
MR. DAVID J. DUNLOP.	MR. JOHN ROBERTSON.
MR. SINCLAIR COUPER.	MR. JOHN MAYER.
MR. W. J. MILLER, *Secretary.*	MR. JOHN MANN, *Treasurer.*

OFFICE-BEARERS OF SECTIONS.

ARCHITECTURAL SECTION.

(As reconstructed at Annual Meeting held 16th March, 1896.)

President.

MR. P. M'GREGOR CHALMERS, Architect, F.S.A.(Scot).

Vice-Presidents.

MR. D. M'BEAN, Architect.
MR. CHARLES CARLTON, Decorator.

Treasurer.

MR. WILLIAM HOWATT, Measurer, 146 Buchanan Street.

Secretary.

MR. A. LINDSAY MILLER, Architect, 122 Wellington Street.

Members of Council.

MR. T. L. WATSON, Architect.
MR. JAMES LINDSAY, Architect.
MR. H. D. WALTON, Architect.
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ADDITIONS TO THE LIBRARY.

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Topeka (Kansas)—
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United States Geological Survey.
United States National Museum (Department of the Interior).
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(Those received in exchange are indicated by an asterisk.)

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Architect.
Athenæum.
British Architect.
British Journal of Photography.
Builder.
Building News.
Chemical News.
Comptes Rendus.
*Dingler's Polytechnisches Journal.
Economist.
Electrical Review.
Electrician.
Engineer.
*Engineering.
English Mechanic.
*Industries and Iron.
*Journal of the Society of Arts.
Journal of Gas Lighting, &c.
*Lancet.
Nature.
Notes and Queries.
*Pharmaceutical Journal.
Publishers' Circular.
Scientific American and Supplement.

FORTNIGHTLY.

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*Berichte der Deutschen Chemischen Gesellschaft.
Journal für Praktische Chemie (Erdmann's).
Zeitschrift für Angewandte Chemie.

MONTHLY.

*American Chemical Journal.
Analyst.
Annalen der Physik und Chemie.
Annales de Chimie et de Physique.
Annales de l'Institut Pasteur.
Annales des Ponts et des Chaussées.
Annales des Sciences Naturelles. Botanique.
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Annals and Magazine of Natural History.
Antiquary.
Beiblätter zu den Annalen der Physik und Chemie.
Bookseller.
Bulletin de la Société Chimique de Paris.
Bulletin de la Société d'Encouragement.
Bulletin de la Société Géologique de France.
Bulletin de la Société Industrielle de Mulhouse.
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*Canadian Entomologist.
*Deutsche Kolonialzeitung.
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Entomologists' Monthly Magazine.
*Geographical Journal.
Geological Magazine.
Science Gossip.
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Journal de Pharmacie et de Chimie.
Journal of Botany.
*Journal of the Chemical Society.
*Journal of the Franklin Institute.
*Journal of the Photographic Society.
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London, Edinburgh, and Dublin Philosophical Magazine.
*Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
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*Scottish Geographical Magazine.
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QUARTERLY.

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Annals of Botany.
Annals of Scottish Natural History.
*Archives Nèerlandaises des Sciences Exactes et Naturelles.
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Forschritte der Mathematik.
Journal of Anatomy and Physiology.
*Journal of the Anthropological Institute of Great Britain.
*Journal of Manchester Geographical Society.
Journal of the Royal Agricultural Society of England.
Journal of the Royal Microscopical Society.
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Quarterly Journal of Economics.
Quarterly Journal of Geological Society.
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*School of Mines Quarterly.
*Sociedad Cientifica "Antonio Alzate."
Zeitschrift für Analytische Chemie.

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5 Sir John William Dawson, LL.D., F.R.S., Principal of M'Gill College, Montreal.	1883
Thomas Muir, M.A., LL.D., F.R.S.E., Superintendent General of Education, Cape Colony.	1892
Langley, Professor S. P., LL.D., D.C.L., Secretary of the Smithsonian Institution, Washington, U.S.A.	1895

BRITISH.

Sir Joseph Dalton Hooker, K.C.B., K.C.S.I., M.D., D.C.L., LL.D., F.R.S., The Camp, Sunningdale.	1874
Herbert Spencer, care of Messrs. Williams & Norgate, 14 Henrietta street, Covent Garden, London.	1879
10 Rev. John Kerr, LL.D., F.R.S., Glasgow.	1885
Sir George Gabriel Stokes, Bart., M.A., LL.D., D.C.L., F.R.S., M.P., Cambridge.	1887
F. Max Müller, M.A., Professor of Comparative Philology, Oxford.	1889
The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., *Sec.*R.S., London, Terling place, Witham, Essex.	1890
Lister, Sir Joseph, Bart., LL.D., D.C.L., *P.*R.S., 12 Park crescent, Portland place, London, W.	1895
15 Geikie, Sir Archibald, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom, 10 Chester terrace, Regent's Park, London, N.W.	1895

CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

A. S. Herschel, M.A., D.C.L., F.R.S., F.R.A.S., Hon. Professor of Experimental Physics in the Durham College of Science, Newcastle-on-Tyne; Observatory House, Slough, Bucks. 1874

Thomas E. Thorpe, Ph.D., F.R.S., Professor of Chemistry in Royal College of Science, London. 1874

John Aitken, F.R.S., F.R.S.E., Burnbrae, Falkirk. 1883

Alex. Buchan, M.A., LL.D., F.R.S.E., Secretary to the Scottish Meteorological Society, 122 George street, Edinburgh. 1883

5 James Dewar, M.A., F.R.S., F.R.S.E., M.R.I., Jacksonian Professor of Physics, University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain, 1 Scroope terrace, Cambridge. 1883

Stevenson Macadam, Ph.D., F.R.S.E., Lecturer on Chemistry, Surgeons' Hall, Edinburgh. 1883

Joseph W. Swan, M.A., F.R.S., Lauriston, Bromley, Kent. 1883

George Anderson, Master of the Mint, Melbourne. 1885

William Milne, M.A., B.Sc., F.R.S.E., Department of Public Education, Cradock, Cape Colony. 1894

ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

* *Denotes Life Members.*

Adam, William, M.A., 235 Bath st. 1876

*Adam, Thomas, 27 Union street. 1892

Adams, William, 28 Ashton terrace, Dowanhill. 1891

Addison, W. H., Superintendent, Deaf and Dumb Institution. 1895

5 Aikman, C. M., M.A., D.Sc., F.R.S.E., F.I.C., F.C.S., 128 Wellington street. 1886

Alexander, D. M., Marionville, Queen's drive. 1887

Alexander, G. W., M.A., 129 Bath street. 1893

Alston, J. Carfrae, 27 James Watt street. 1887

Anderson, Alexander, 157 Trongate. 1869

10 Anderson, James, 168 George street. 1890

Anderson, John, 22 Ann street. 1884

Anderson, J. B. Mackenzie, M.B., 42 Lansdowne crescent. 1895

Anderson, Robert, 22 Ann street. 1887

Anderson, Robert, 76 Bath street. 1896

15 Anderson, R. T. R., 618 Gallowgate street. 1889

*Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 2 Woodside terrace. 1873

*Anderson, William, 284 Buchanan street. 1890

Anderson, W. F. G., 47 Union street. 1878

*Annan, J. Craig, 234 Sauchiehall st. 1888

20 Annandale, Charles, M.A., LL.D., 35 Queen Mary avenue. 1888

Arnot, James Craig, 162 St. Vincent street. 1869

*Arnot, J. L., 116 West Campbell st. 1890

Arnot, William, City Chambers. 1894

Atkinson, J. B., 10 Foremount terrace, Partick. 1889

25 Bain, Andrew, 17 Athole gardens. 1890

Bain, Sir James, F.R.S.E., 3 Park terrace. 1866

Bain, Robert, 132 West Nile street. 1869

*Baird, J. G. A., M.P., Wellwood, Muirkirk. 1892

Balloch, Robert, Eamont lodge, Dowanhill. 1843

30 Balmain, Thos., 1 Kew terrace, Kelvinside. 1881

Barclay, A. J. Gunion, M.A., F.R.S.E., High School. 1893

Barclay, A. P., 133 St. Vincent street. 1890

Barclay, George, 6 Colebrooke ter. 1891

Barclay, James, 36 Windsor terrace. 1871

35 Barrett, Francis Thornton, Mitchell Library, *Vice-President.* 1880

Barr, Archibald, D.Sc., Professor of Civil Engineering and Mechanics in the University of Glasgow, Royston, Dowanhill. 1890

*Barr, James, C.E., I.M., F.S.I., 221 West George street. 1883

Barr, Thos., M.D., F.F.P.S.G., 13 Woodside place, W. 1879

Bathgate, William, M.A., 13 Westbourne gardens. 1887

40 Bayne, A. Malloch, 13 Kelvin drive, Kelvinside. 1878

Beatson, George T., B.A. (Cantab.), M.D., 7 Woodside crescent. 1881

Begg, Wm., 636 Springfield road. 1883

Becker, L., Ph.D., Professor of Astronomy in the University of Glasgow, The Observatory. 1895
Beilby, George T., F.I.C., St. Kitts, Slateford. 1895
45*Beith, Gilbert, 15 Belhaven terrace. 1881
Bell, Dugald, F.G.S., 27 Lansdowne crescent. 1871
*Bell, Henry, 39 Fitzjohn's avenue, Hampstead, London, N.W. 1876
Bell, Sir James, Bart., 101 St. Vincent street. 1877
Bennett, Robert J., Alloway park, Ayr. 1883
50 Biles, J. H., Professor of Naval Architecture and Marine Engineering, University of Glasgow. 1893
Bilsland, William, 28 Park circus. 1888
Black, D. Campbell, M.D., M.R.C.S.E., Professor of Physiology, Anderson's College Medical School, 121 Douglas street. 1872
Black, J. Albert, Duneira, Row. 1869
Black, Malcolm, M.D., 5 Canning place. 1880
55*Blackie, J. Alexander, 17 Stanhope street. 1881
*Blackie, J. Robertson, 17 Stanhope st. 1881
Blackie, W. G., Ph.D., LL.D., F.R.G.S., 17 Stanhope street. 1841
*Blackie, Walter W., B.Sc., 17 Stanhope street. 1886
Blair, G. M'Lellan, 2 Lilybank ter. 1869
60 Blair, J. M'Lellan, Williamcraig, Linlithgowshire. 1869
Blair, Matthew, 5 Hampton Court terrace. 1887
Blyth, James, M.A., F.R.S.E., Professor of Natural Philosophy, Andersonian Buildings, 204 George street. 1881
*Blyth, Robert, C.A., 1 Montgomerie quadrant. 1885
*Blythswood, The Rt. Hon. Lord, Renfrew. 1885
65*Borland, William, 142 St. Vincent street. 1895
Borthwick, James D., 3 Balshagray terrace, Partick. 1891
Bottomley, James T., M.A., D.Sc., F.R.S., F.R.S.E., F.C.S., Demonstrator in Natural Philosophy, University of Glasgow, 13 University gardens, Hillhead. 1880
Bottomley, Wm., C.E., 15 University gardens. 1880
Bower, F. O., D.Sc., M.A., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow, 45 Kersland terrace. 1885
70 Boyd, John, Shettleston Iron-works, near Glasgow. 1873
Brier, Henry, M.I.M.E., 13 Ailsa drive. 1889
Brodie, John Ewan, M.D., C.M., F.F.P.S.G., 5 Woodside place. 1873
Brown, Alexander, 3 Queen's terrace. 1887
Brown, Alex., The Craigs, Carmunnock. 1896
75*Brown, Hugh, 5 St. John's terrace, Hillhead. 1887
Brown, James, 76 St. Vincent st. 1876
*Brown, John, 11 Somerset place. 1881
Brown, Richard, 138 West George street. 1895
Brown, Robert, 19 Jamaica street. 1882
80*Brown, Wm. Stevenson, 41 Oswald street. 1886
*Brown, William, 165 W. George st. 1892
Browne, Richard, Beechholm, Queen's drive, Crosshill. 1893
Browne, Robert, B.Sc., 45 Washington street. 1893
Brownlie, Archibald, Bank of Scotland, Barrhead. 1880
85 Brownlie, J. Rankin, L.D.S.(Eng.), 220 West George street. 1892
*Bryce, Robert, 82 Oswald street. 1886
Buchanan, Alex. M., A.M., M.D., Professor of Anatomy, Anderson's College Medical School, 98 St. George's road. 1876
Buchanan, George S., 85 Candleriggs. 1845
*Buchanan, Wm., Enderley, Bearsden. 1886
90 Burnet, John, F.R.I.B.A., I.A., 167 St. Vincent street. 1850
Burnet, John James, A.R.S.A., F.R.I.B.A., 18 University avenue. 1892
Burns, J., M.D., 15 Fitzroy place, Sauchiehall street. 1864

*Caldwell, George B., Scotia Leather Works, Boden street. 1892
Cameron, Sir Charles, Bart., M.D., LL.D., Greenock. 1870
95 Cameron, H. C., M.D., 200 Bath street. 1873
*Campbell, Archibald, Springfield quay. 1895
*Campbell, J. A., LL.D., M.P., Stracathro, Brechin. 1848
*Campbell, James, 137 Ingram st. 1885
*Campbell, John Ferguson, 2 Holborn terrace, N., Kelvinside. 1892
100 Campbell, John MacNaught, C.E., F.Z.S., F.R.S.G.S., Kelvingrove Museum. 1883
*Campbell, Louis, 3 Eton terrace, Hillhead. 1881
Campbell, Malcolm, 18 Gordon street. 1894

Campbell, Thomas, Maryhill Iron-works. 1894
Carlile, Thomas, 23 West Nile st. 1851
105 Carmichael, Neil, M.D., C.M., F.F.P.S.G., Invercarmel, 23 Nithsdale drive, Pollokshields. 1873
Carver, Thomas, A.B., B.Sc., C.E., Heigham, Aubrey road, Hornsey, London, N. 1890
Cassells, John, 62 Glencairn drive, Pollokshields. 1890
Cassells, Robert Dunlop, B.Sc., 62 Glencairn drive, Pollokshields. 1895
*Cayzer, Charles W., M.P., 109 Hope street. 1886
110 Chalmers, A. K., M.D., D.P.H. (Camb.), 23 Kersland terrace. 1892
Chalmers, James, I.A., 93 Hope street. 1884
Chalmers, P. MacGregor, F.S.A.Scot., 95 Bath street. 1891
Cherrie, James M., Clutha cottage, Tollcross. 1876
*Chisholm, Samuel, 4 Royal ter., W. 1890
115 *Christie, Henry W., Levenfield house, Alexandria. 1892
Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868
Chrystal, W. J., F.I.C., F.C.S., Shawfield Works, Rutherglen. 1882
Clapperton, Charles, 175 West George street. 1882
Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870
120 Clark, John, 9 Wilton crescent. 1872
*Clark, William, 125 Buchanan st. 1876
*Cleland, John, M.D., LL.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 1884
*Coats, Joseph, M.D., Professor of Pathology in the University of Glasgow, 8 University gardens, *Vice-President*. 1873
*Cochran, Robert, 7 Crown circus, Dowanhill. 1877
125 Coghill, Wm. C., 263 Argyle street. 1873
*Colquhoun, James, LL.D., 158 St. Vincent street. 1876
Colville, James, M.A., D.Sc., 14 Newton place. 1885
Combe, James Russell, 257 West Campbell street. 1895
Connell, William, 42 St. Enoch square. 1870
130 Cooke, Louis H., A.R.S.M., 1 Kenmure terrace, Pollokshields. 1893
Copland, Wm. R., M.Inst.C.E., F.S.I., 146 West Regent street. 1876
Core, Wm., M.D., Medical Superintendent, Barnhill Hospital. 1891
Coste, Jules, French Consulate, 131 West Regent street. 1888
Costigane, John T., Limekilns house, East Kilbride. 1889
135 Costigane, William, Clifton hall, Albert drive, Pollokshields. 1890
Coubrough, A. Sykes, Parklea, Blanefield, Strathblane. 1869
Coulson, W. Arthur, 57 West Nile street. 1888
Couper, James, Craigforth house, Stirling. 1862
Couper, Sinclair, Moore Park Works, Helen street, Govan. 1896
140 Cowan, M'Taggart, C.E., 27 Ashton terrace, Hillhead. 1876
Craig, T. A., C.A., 139 St. Vincent street. 1886
Crawford, Wm. C., M.A., Lockharton gardens, Slateford, Edinburgh. 1869
Cree, Thomas S., 21 Exchange square. 1869
Crichton, James, 201 Nithsdale road, Pollokshields. 1892
145 Crosbie, L. Talbot, Scotstounhill, Whiteinch. 1890
Cross, Alexander, M.P., 14 Woodlands terrace. 1887
*Crum, Walter G., Thornliebank. 1895
Curphey, Wm. Salvador, 15 Bute mansions, Hillhead 1883
Cuthbert, Alexander A., 14 Newton terrace. 1885
150 *Cuthbertson, Sir John N., LL.D., 29 Bath street. 1850

Dansken, A. B., 105 West George street. 1877
*Dansken, John, I.M., F.S.I., F.R.A.S., 241 West George street. 1876
Darling, Geo. E., 178 St. Vincent street. 1870
Davey, Arthur J., London Road Iron-works. 1895
155 Deas, Jas., C.E., 7 Crown gardens, Dowanhill. 1869
Dempster, John, 4 Belmar terrace, Pollokshields. 1875
Dennison, William, C.E., 175 Hope street. 1876
*Dick, George Handasyde, 136 Buchanan street. 1887
*Dixon, A. Dow, 10 Montgomerie crescent, Kelvinside. 1873
160 Dixon, Walter, 164 St. Vincent street. 1893
Dobbie, A. B., M.A., University. 1885
Dobson, James, Springfield avenue, Uddingston. 1892
Donald, John, Townhead Public School. 1872
Donald, William J. A., 70 Great Clyde street. 1877

165 Donaldson, James, Gas-works, Cambuslang. 1890
Dougall, Franc Gibb, 167 Canning street. 1875
Dougall, John, M.D., C.M., F.F.P.S.G., Professor of Materia Medica, St. Mungo's College, 493 Shields road. 1876
Douglas, Campbell, I.A., F.R.I.B.A., 266 St. Vincent street. 1870
Dowie, George, 101 St. Vincent st. 1896
170 Downie, Robert, jun., Carntyne Dye-works, Parkhead. 1872
Downie, Thomas, Hydepark Foundry. 1886
*Dreghorn, David, Smith st., Kinning Park. 1896
Duncan, Eben., M.D., C.M., F.F.P.S.G., Queen's Park house, Langside road, *President.* 1873
Duncan, Hugh, M.A., LL.B., 175 West George street. 1895
175*Duncan, Robert, Whitefield Works, Govan. 1890
*Duncan, Walter, 7 West George st. 1881
*Dunlop, Nathaniel, 25 Bothwell street. 1870
Dunn, Robert Hunter, 4 Belmont crescent. 1878
Dyer, Henry, M.A., D.Sc., C.E., 8 Highburgh terrace, Dowanhill. 1883

180 Eadie, Alexander, 280 Cathcart road. 1885
*Edwards, John, Govanhaugh Dye-works, M'Neil street. 1883
Elgar, Francis, LL.D., F.R.S., 113 Cannon street, London, E.C. 1884
*Ellis, T. Leonard, North British Iron-works, Coatbridge. 1888
Erskine, Jas., M.A., M.B., L.F.P.S.G., 351 Bath street. 1886
185*Ewing, Wm., 62 Buchanan street. 1883

Fairweather, Wallace, C.E., 62 St. Vincent street. 1880
Falconer, Patrick, 33 Hayburn crescent, Partick. 1876
Falconer, Thos., 50 Kelvingrove st. 1880
Farquhar, John, 13 Belhaven terrace. 1872
190 Farquhar, Wm. R., Marymar, Kilmalcolm. 1892
Fawsitt, Charles A., 9 Foremount terrace, Partick. 1879
*Fergus, Freeland, M.D., F.F.P.S.G., 203 Bath street. 1887
*Ferguson, John, M.A., LL.D., F.R.S.E., Professor of Chemistry, University of Glasgow, *Hon. Vice-President.* 1869
Ferguson, John Forbes, 138 West George street. 1895
195 Ferguson, Joshua, M.A., Enfield house, Crosshill. 1895
Ferguson, Peter, 15 Bute gardens, Hillhead. 1866
Fergusson, Alex. A., 48 M'Alpine street. 1847
Findlay, Joseph, Clairmont, Winton drive, Kelvinside. 1873
Finlayson, James, M.D., 2 Woodside place. 1873
200*Fleming, James, 136 Glebe street. 1880
*Fleming, William James, M.D., 3 Woodside terrace. 1876
Fotheringham, T. B., 65 West Regent street. 1889
Foulis, William, C.E., 45 John st. 1870
*Fowler, John, 5 Derby street, Sandyford. 1880
205 Frame, James, Union Bank of Scotland, 113 King street, Tradeston. 1885
Fraser, Melville, 31 St. Vincent place. 1890
Frazer, Daniel, 127 Buchanan st. 1853
Frazer, Samuel M'Call, 127 Buchanan street. 1896
Frew, Alex., C.E., 175 Hope street. 1876
210 Fulton, David, 6 Wilton crescent. 1891
Fulton, R. C., 14 Hamilton Park terrace. 1890
Fyfe, Henry B., 115 St. Vincent street. 1892

Gairdner, Charles, LL.D., Broom, Newton-Mearns. 1884
*Gairdner, C. D., C.A., 115 St. Vincent street. 1886
215 Gairdner, W. T., M.D., LL.D., F.R.S., Professor of Practice of Medicine in the University of Glasgow, 225 St. Vincent street. 1863
Galbraith, Peter, 17 Huntly gardens. 1889
Galbraith, Walter M., 7 Holyrood crescent. 1893
Gale, James M., C.E., 45 John st. 1856
Galloway, T. Lindsay, C.E., 43 Mair street, Plantation. 1881
220 Gardner, Daniel, 36 Jamaica street 1869
*Garrow, James R., 6 Pollock road. 1890
*Garroway, John, 694 Duke st. 1875
Geddes, Wm., 8 Battlefield crescent, Langside. 1846
Gibson, Charles R., St. Mirren's Mills, Paisley. 1895
225 Gillies, W. D., 17 Royal Exchange square. 1872
Gilfillan, Wm., 129 St. Vincent st. 1881
Glaister, John, M.D., F.F.P.S.G., D.P.H.(Camb.), &c., Professor of Medical Jurisprudence and Public Health, St. Mungo's College, 4 Grafton place. 1879

Goldie, James, 52 St. Enoch square. 1883
Goodwin, Robert, 58 Renfield street. 1875
230 Gourlay, John, C.A., 24 George square. 1874
Gow, Leonard, 19 Waterloo street. 1889
Gow, Leonard, jun., 19 Waterloo street. 1884
Gow, Robert, Cairndowan, Dowanhill gardens. 1860
Graham, Alex. M., Rowanlea, 7 St. Andrew's drive, Pollokshields. 1887
235 *Graham, Robert, 108 Eglinton st. 1888
*Graham, William, B.L., 11 Claremont terrace. 1885
Gray, Andrew, 30 Bath street. 1889
Gray, James, M.D., 15 Newton terrace. 1863

Halket, George, M.D., F.F.P.S.G., 4 Royal cres., W. 1889
240 Hamilton, Don., Brandon, Uddingston. 1894
*Hamilton, John, I.A., 212 St. Vincent street. 1885
Harley, George, 29 Burnbank gardens. 1891
*Harvie, John, Secretary, Clydesdale Bank, 30 St. Vincent place. 1880
Harvie, William, 8 Bothwell terrace, Hillhead. 1888
245 Hassard, William John, 209 Sauchiehall street. 1895
Hedderwick, Maxwell, 22 St. Vincent place. 1892
Henderson, Alex., Barnhill Poorhouse. 1894
*Henderson, A. P., 20 Newton place. 1880
Henderson, George G., M.A., D.Sc., F.I.C., F.C.S., Professor of Chemistry, Glasgow and West of Scotland Technical College, 204 George street. 1883
250 Henderson, John, 38 Berkeley st. 1893
*Henderson, John, Meadowside Works, Partick. 1879
Henderson, John, Towerville, Helensburgh. 1890
Henderson, Robert, 167 West Regent street. 1885
*Henderson, William, 15 Cadogan street. 1873
255 Hendrick, James, B.Sc., F.C.S., 60 John street. 1893
Hendry, George Scott, 87 Bothwell street. 1895
Henry, R. W., 62 Kelvingrove street. 1875
Heys, Zechariah J., South Arthurlie, Barrhead. 1870
Higgins, Henry, jun., 248 West George street. 1878
260 Hodge, William, 27 Montgomerie drive, Kelvinside. 1878
Hogg, Robert, 9 Nithsdale drive, Pollokshields. 1865
Horton, William, Birchfield, Mount Florida. 1889
Houstoun, Wm. Henry, Hillcrest, Cambridge drive. 1895
Howat, William, 37 Elliot street. 1885
265 Howatt, Wm., I.M., 146 Buchanan street. 1870
Hunt, Edmund, 181 West George street. 1856
*Hunt, John, Milton of Campsie. 1881
*Hunter, Wm. S., 30 Hope street. 1889
Hutchison, Peter, 3 Lilybank terrace, Hillhead. 1889

270 Inglis, John, Pointhouse Shipyard. 1895
Inglis, R. A., Culrain, Bothwell. 1889

*Jack, William, M.A., LL.D., Professor of Mathematics in the University of Glasgow. 1881
Jamieson, Andrew, F.R.S.E., M.Inst.C.E., M.Inst.E.E., &c., Professor of Electrical Engineering, Glasgow and West of Scotland Technical College, 16 Rosslyn terrace, Kelvinside. 1881
Jenkins, Thomas Wilson, M.A., M.D., 1 Newark drive. 1892
275 Johnston, David, 160 West George st. 1891
Johnstone, Jas., Coatbridge street, Port-Dundas. 1869
Jolly, William, F.G.S., F.R.S.E., Greenhead house, Govan. 1890

Kay, Wm. E., F.C.S., Gowanbank, Clarkston, Busby. 1887
Kean, James, 32 Scotia street, Garnethill. 1888
280 Kelly, James K., M.D., F.F.P.S.G., Park villa, Queen Mary avenue, Crosshill. 1889
Kelvin, The Right Hon. Lord, LL.D., D.C.L., P.R.S., F.R.S.E., Professor of Natural Philosophy, University of Glasgow, *Hon. Vice-President.* 1846
Kennedy, James, 33 Greendyke street. 1889
Ker, Charles, M.A., C.A., 115 St. Vincent street. 1885
*Ker, Wm., 1 Windsor ter., west. 1874
285 Kerr, Adam, 175 Trongate. 1887
Kerr, Charles James, 40 West Nile street. 1877
Kerr, Geo. Munro, 97 Buchanan street. 1890
Kerr, John G., M.A., 15 India street. 1878

Key, William, 109 Hope street. 1877
290 King, James, 57 Hamilton drive, Hillhead. 1848
King, Sir James, Bart., LL.D., of Campsie, 115 Wellington street. 1855
King, John, Tigh Ruadh, Possilpark. 1895
King, John Y., 142 St. Vincent street. 1893
Kirk, Robert, M.D., Newton cottage, Partick. 1877
295 Kirkpatrick, Alexander B., 88 St. Vincent street. 1885
Kirkpatrick, Andrew J., 179 West George street. 1869
Kirkwood, James, Carling lodge, Ibrox. 1890
Knight, James, M.A., B.Sc., F.C.S., F.G.S., The Shieling, Uddingston. 1893
Knox, Adam, 47 Crownpoint road. 1881
300 *Knox, David J., 19 Renfield street. 1890
Knox, John, 58 Bath street. 1883

Laird, George H., 3 Seton terrace, Dennistoun. 1882
Laird, John, Marchmont, Port-Glasgow. 1876
Laird, John, Royal Exchange Sale Rooms. 1879
305 Lamb, David, 3 Albion place, Dowanhill. 1896
Lamond, Robert, 8 Marchmount terrace, Kelvinside. 1894
Lang, William, F.C.S., Crosspark, Partick, *Vice-President.* 1865
*Lauder, James, F.R.S.L., Glasgow Athenæum. 1892
Lauder, John, 87 Union street. 1894
310 Leitch, Alexander, 60 Rosebank terrace, Grant street. 1886
Leslie, John A., jun., 48 Cadogan street. 1894
*Lindsay, Archd. M., M.A., 87 West Regent street. 1872
Lodge, Professor Richard, M.A., The University. 1895
Lothian, Alex. V., M.A., 11 Holborn terrace. 1893
315 Love, James Kerr, M.D., C.M., 10 Newark drive. 1888
Lundholm, C. O., Nobel's Explosives Factory, Ardeer, Stevenston. 1890

M'Ara, Alexander, 65 Morrison street 1888
MacArthur, J. G., Rosemary villa, Bowling. 1874
*MacArthur, John S., 108A Hope street. 1890
320 M'Bain, W. C., 75 Jamaica street. 1895
M'Callum, Robert, jun., 69 Union street. 1891
*M'Clelland, Andrew Simpson, C.A., 4 Crown gardens, Dowanhill. 1884
M'Conville, John, M.D., 27 Newton place. 1870
M'Cracken, James, 5 Bowmont terrace, Kelvinside. 1889
325 M'Crae, John, 7 Kirklee gardens, Kelvinside. 1876
M'Creath, James, M.E., 208 St. Vincent street. 1874
M'Culloch, Hugh, 154 West Regent street. 1880
Macdonald, Archibald G., 8 Park circus. 1869
*Macdonald, John, 72 Great Clyde street. 1896
330 Macdonald, Thomas, 50 Gibson street, Hillhead. 1869
*Macfarlane, Walter, 12 Lynedoch crescent. 1885
M'Farlane, Wm., Edina lodge, Rutherglen. 1888
*M'Gilvray, R. A., 129 West Regent street. 1880
M'Gregor, Duncan, F.R.G.S., 37 Clyde place. 1867
335 M'Houl, David, Ph.D., Dalquhurn Works, Renton. 1883
*Macindoe, Alex., C.A., 104 West George street 1894
Macintosh, Donald J., M.B., C.M., Western Infirmary. 1894
Macintyre, John, M.B., C.M., 179 Bath street. 1895
M'Intyre, Wm., Marion bank, Rutherglen. 1888
340 M'Kellar, John C., 112 Bath street. 1896
M'Kellar, J., 25 Kelvinside terrace. 1893
*M'Kendrick, John G., M.D., C.M., LL.D., F.R.S., F.R.S.E., F.R.C.P.E., Professor of Institutes of Medicine in the University of Glasgow, 2 Florentine gardens, *Hon. Vice-President.* 1877
*M'Kenzie, W. D., 43 Howard street. 1875
*M'Kenzie, W. J., 18 Melrose gardens, North Kelvinside 1879
345 Mackinlay, David, 6 Great Western terrace, Hillhead. 1855
*Mackinlay, James Murray, 4 Westbourne gardens. 1886
M'Kissack, John, 68 West Regent street. 1881
Maclae, A. Crum, 147 St. Vincent street. 1884
M'Laurin, Robert, 347 Gairbraid street, Maryhill. 1895
350 *Maclay, David T., 169 W. George street. 1879

Maclay, W., Eildon villas, Mount Florida. 1893
Maclean, A. H., 8 Hughenden terrace, Kelvinside. 1870
Maclean, Magnus, M.A., F.R.S.E., D.Sc., 8 St. Albans ter, Hillhead. 1885
MacLehose, James J., M.A., 61 St. Vincent street. 1882
355 *Macleod, A., 3 Dundas street. 1893
M'Lennan, James, 40 St. Andrew's street. 1888
Macnair, D. S., Ph.D., B.Sc., Glenogle, Kilmalcolm. 1895
Macouat, R. B., 37 Elliot street 1885
Macphail, Donald, M.D., Garturk cottage, Whifflet, Coatbridge. 1877
360 M'Pherson, George L., 30 Albert road, Crosshill, East. 1872
M'Vail, D. C., M.B., Professor of Clinical Medicine, St. Mungo's College, 3 St. James' terrace, Hillhead. 1873
Machell, Thomas, 1 Burnbank terrace, 1886
Main, Robert B., 56 Dalziel drive. 1885
Mann, John, C.A., 188 St. Vincent street, *Treasurer.* 1856
365 Mann, John, jun., M.A., C.A., 188 St. Vincent street. 1885
Manwell, James, The Hut, 4 Albert drive, Pollokshields. 1876
Marshall, T. Rhymer, D.Sc., Professor of Chemistry in St. Mungo's College, 11 Woodside crescent. 1894
Martin, Jas. F., 63 Brunswick st. 1895
Martin, William, 116 St. Vincent street. 1892
370 Marwick, Sir J. D., LL.D., F.R.S.E., 19 Woodside terrace. 1878
Mathie, George M., 15 Wardlawhill terrace, Rutherglen. 1895
Mathieson, J. H., 9 Grosvenor ter., Kelvinside. 1896
Mavor, Henry A., 57 West Nile street. 1887
Mavor, James, The University, Toronto, Canada. 1885
375 Mavor, Samuel, 3 Elmbank cres. 1890
Mayer, John, Strathview, Cathkin road, Langside, *Secretary.* 1860
Mechan, Arthur, 60 Elliot street. 1876
Mechan, Henry, 60 Elliot street. 1879
Meikle, Andrew W., M.A., Viewfield house, Pollokshields. 1890
380 Menzies, Thos., Hutchesons' Grammar School, Crown street. 1859
*Menzies, Thos. J., M.A., B.Sc., F.C.S., 211 Crown street, S.S. 1887
Menzies, William Crawford, City Improvement Trust, 34 Trongate. 1895
Millar, James, 158 Parliamentary road. 1870
Miller, A. Lindsay, 122 Wellington street. 1878
385 *Miller, Arch. Russell, Castlebank, Bothwell. 1884
Miller, Major David S., 8 Royal crescent, W. 1887
*Miller, George, Winton drive, Kelvinside. 1881
Miller, G. J., Frankfield, Shettleston. 1888
Miller, John (Messrs. James Black & Co.), 23 Royal Exchange square. 1874
390 Miller, Richard, 6 Dixon street. 1885
*Miller, Thos. P., Cambuslang Dye-works. 1864
Milligan, Thomas R., 22 Arlington street. 1892
Mills, Edmund J., D.Sc., F.R.S., "Young" Professor of Technical Chemistry, 60 John street. 1875
Mirrlees, James B., Redlands, Kelvinside. 1869
395 *Mirrlees, William J., 45 Scotland st. 1889
*Mitchell, George A., 5 West Regent street. 1883
Mitchell, Robert, 12 Wilson street, Hillhead. 1870
*Moffatt, Alexander, 23 Abercromby place, Edinburgh. 1874
Mollison, James, 6 Hillside gardens, Partick. 1889
400 *Mond, Robert Ludwig, B.A. (Cantab), F.R.S.E., 20 Avenue road, Regent's park, London, N.W. 1890
*Monteith, Robert, Greenbank, Dowanhill gardens. 1885
Moore, Alexander, C.A., 209 West George street. 1869
Moore, Alexander George, M.A., B.Sc., 13 Clairmont gardens. 1886
Morrice, Jas. A., 1 Prince's ter., Dowanhill. 1883
405 Motion, James Russell, 38 Cochrane street. 1887
Muir, Alex., 400 Eglinton street. 1883
*Muir, Allan, Ardmay, Newlands road, Langside. 1881
Muir, James, C.A., 149 West George street. 1887
Muir, Sir John, Bart., 22 West Nile Street. 1876
410 *Muirhead, Andrew Erskine, Cart Forge, Crossmyloof. 1873
Muirhead, James, 2 Bowmont gardens, Kelvinside. 1887
*Muirhead, Robert F., M.A., B.Sc., 61 Warrender Park road, Edinburgh. 1879
Munro, Daniel, F.S.I., 10 Doune terrace, Kelvinside. 1867

Munro, J. Pearson, M.B., C.M., 69 Bank street, Hillhead. 1893
415 Munsie, George, 1 St. John's ter., Hillhead. 1871
Munsie, Robert George, 10 Berkeley terrace, West. 1883
Murdoch, George, 40 St. Vincent pl. 1894
*Murdoch, Robert, 91 Maxwell road. 1880
*Murray, David, LL.D., 169 West George street. 1876
420 Murray, John Bruce, 12 Mitchell street. 1890
Murrie, James, 264 St. Vincent st. 1892

Napier, Alex., M.D., F.F.P.S.G., Rose Bank, Queen Mary avenue, Crosshill. 1886
Napier, James, 15 Prince's square, Strathbungo. 1870
*Napier, John, 23 Portman square, London. 1846
425 Nelson, Alex., 80 Gordon street. 1880
*Newlands, Joseph F., 28 Renfield st. 1883

Orr, Robert, 79 West Nile street. 1890
Osborne, Alex., 4 Kew terrace. 1870
Osborne, Robert, 3 Montgomerie crescent. 1890

430 Park, James, 51 Millburn street. 1877
Park, Robert, M.D., 40 Grant st. 1894
*Parker, John Dunlop, C.E., 146 West Regent street. 1889
*Parnie, James, F.S.I., 32 Lynedoch street. 1874
*Paterson, Robert, C.A., 28 Renfield street. 1881
435 Paton, James, F.L.S., Corporation Galleries, and Kelvingrove Museum. 1876
Patrick, Joseph, M.A., C.A., 203 West George street. 1893
Patterson, T. L., F.C.S., at John Walker & Co.'s, Greenock. 1873
Petrie, Alexander, I.A., 134 Wellington street. 1885
Pirie, John, M.D., 26 Elmbank crescent. 1877
440 *Pirrie, Robert, 9 Buckingham ter. 1875
*Pollock, R., M.B., C.M., F.F.P.S.G., Laurieston house, Pollokshields. 1883
Prince, Edward E., B.A. (Cantab), F.L.S., Ottowa, Canada. 1892
Pringle, Patrick James, 115 Mains street. 1892
*Provan, James, 40 West Nile st. 1868
445 Provand, A. D., M.P., 8 Bridge street, London, S.W. 1888

Raalte, Jacques Van, 105 West George street. 1884
Ramsey, Robert, 14 Park terrace. 1889
Rankine, David, C.E., 238 West George street. 1875
Rattray, Rev. Alex., M.A., Parkhead Parish, 4 Westercraigs, Dennistoun. 1879
450 Rattray, William A., 233 Hope st. 1890
Reid, David, 16 Cambridge street. 1887
*Reid, Hugh, Belmont, Springburn. 1880
Reid, James, 15 Montgomerie cres. 1889
Reid, Thos., M.D., LL.D., 11 Elmbank street. 1869
455 Reid, William, M.A., 61 Grant st. 1881
*Reid, William L., M.D., Professor of Midwifery, Anderson's College Medical School, 7 Royal crescent, West. 1882
Reith, Rev. George, M.A., D.D., Free College Church, 37 Lynedoch st. 1876
Renton, James Crawford, M.D., L.R.C.P.& S.Ed., 1 Woodside ter. 1875
Rey, Hector, B.L., B.Sc., Ailsa ter. 1889
460 Richmond, Thos., L.R.C.P.E., 2 West Garden street. 1887
Ritchie, George, Parkhead Forge and Steel Works. 1890
Robertson, John, Woodside school, Endcliffe, Langside, *Librarian.* 1860
Robertson, J. M'Gregor, M.A., M.B., C.M., 26 Buckingham ter., Hillhead. 1881
Robertson, Robert A., 8 Park Circus place. 1877
465 Robertson, Robert H., Clyde bank, Rutherglen. 1888
Robertson, William, C.E., 123 St. Vincent street. 1869
*Rogers, John C., 224 St. Vincent st. 1888
Rose, Alexander, Richmond house, Dowanhill. 1879
*Rose, Charles A., Belmont, Dowanhill gardens. 1889
470 Ross, David, M.A., B.Sc., LL.D., E.C. Training College. 1888
Ross, Henry, 7 Park quadrant. 1876
*Ross, John, 9 Westbourne gardens. 1885
Ross, John Munn, C.A., 115 Wellington street. 1894
Ross, William, 10 Regent place, Shawlands. 1893
475 Rottenburg, Paul, 105 West George street. 1872
Rowan, David, 22 Woodside place. 1863
Rowan, W. G., 234 West George street. 1881
Rundell, R. Cooper, Underwriters' Room, Royal Exchange. 1877
Russell, James B., B.A., M.D., LL.D., 3 Foremount terrace, Partick, *Hon. Vice-President.* 1862
480 Salmon, W. Forrest, F.R.I.B.A., 197 St. Vincent street. 1870

Sawers, Wm. D., Assoc. I.C., 7 Buckingham street, Hillhead. 1894
Sayers, William Brooks, 189 St. Vincent street. 1890
Schmidt, Alfred, 508 New City rd. 1881
Sclanders, David, jun., 71 Waterloo street. 1895
485 Scott, Alex., 2 Lawrence place, Dowanhill. 1871
*Scott, D. M'Laren, 2 Park quad. 1881
Scott, John, 54 Scott street. 1891
Scott, John, 245 Sauchiehall st. 1892
Scott, Robt., I.M., 115 Wellington street. 1884
490 Seligmann, Hermann L., 59 St. Vincent street. 1850
Sexton, A. Humboldt, F.C.S., F.I.C., F.R.S.E., Professor of Metallurgy, Glasgow and West of Scotland Technical College, 204 George street. 1892
Simons, Michael, 206 Bath street. 1880
Sinclair, Alexander, Ajmere lodge, Langside. 1883
Sloane, F. N., C.A., 187 West George street. 1893
495 Smart, William, M.A., LL.D., Nunholm, Dowanhill. 1886
Smellie, George, I.M., 167 St. Vincent street. 1880
*Smellie, Thos. D., F.S.I. 209 St. Vincent street. 1871
Smith, Alex. Muir, M.D., C.M., 13 Montgomerie street, North Kelvinside. 1895
Smith, D. Johnstone, C.A., 149 W. George street. 1888
500 Smith, Francis, Ashfield, Bothwell. 1875
Smith, Harry J., Ph.D., 6 South Hanover street. 1877
Smith, Hugh C., 55 Bath street. 1861
*Smith, J. Guthrie, 54 West Nile street. 1875
*Smith, Robert B., Bonnybridge, Stirlingshire. 1884
505*Smith, W. B., 31 Queen street. 1895
Snodgrass, James, F.C.S., 2 Keir terrace, Pollokshields. 1878
Snodgrass, William, M.A., M.B., C.M., Muirhead Demonstrator of Physiology, University of Glasgow, 11 Victoria crescent, Dowanhill. 1890
*Somerville, Alexander, B.Sc., F.L.S., 4 Bute Mansions, Hillhead street, Hillhead. 1888
Sorley, Robert, 3 Buchanan st. 1878
510 Spencer, Charles L., Edgehill, Kelvinside. 1891
Spencer, J. J., Edgehill, Kelvinside. 1895
Spens, John A., 169 W. George street. 1879
*Spiers, John, 493 Great Western road, Hillhead. 1885
Stanford, Edward C. C., F.C.S., Glenwood, Dalmuir, Dumbartonshire. 1864
515*Steel, William Strang, Philiphaugh, Selkirk. 1889
*Stephen, John, Domira, Partick. 1880
*Steven, Hugh, Westmount, Montgomerie drive. 1869
Steven, John, 32 Elliot street. 1875
*Stevenson, D. M., 12 Waterloo street. 1889
520*Stevenson, Jas., F.R.G.S., 23 West Nile street. 1870
Stevenson, John, C.E., 208 St. Vincent street. 1885
Stevenson, John, 12 Victoria road, Lenzie. 1892
Stevenson, Wm., 21 Clyde place. 1888
Stewart, Andrew, 41 Oswald street. 1887
525 Stewart, Archibald, Marnock villa, Queen's drive, Crosshill. 1892
Stewart, Daniel Rankin, Osborne cottage, Broxburn, West Lothian. 1895
Stewart, David, 3 Clifton place. 1856
*Stobo, Thomas, Somerset house, Garelochhead. 1884
Stoddart, James Edward, Howden, Mid-Calder, N.B. 1872
530*Strain, John, C.E., 154 West George street. 1876
Strathie, David, C.A., 162 St. Vincent street. 1895
*Sutherland, David, Royal Marine Hotel, Nairn. 1880
*Sutherland, John, Great Western Hotel, Oban. 1880
Sutherland, J. R., C.E., 45 John street. 1884
535 Swan, Charles C., 1 Rose street, Garnethill. 1891

Tatlock, John, F.I.C., 13 Parkgrove terrace, West, Sandyford. 1875
Tatlock, Robt. R., F.R.S.E., F.I.C., F.C.S., 156 Bath street. 1868
Taylor, Benjamin, F.R.G.S., 10 Derby crescent, Kelvinside. 1872
Teacher, Adam, 14 St. Enoch square. 1868
540 Teague, Francis, M.I.E.E., Electric Lighting Station, Coatbridge. 1894
Tennant, Sir Charles, Bart., 195 West George street. 1868
Tennent, Gavin P., M.D., 159 Bath street. 1875
Thomas, Moses, M.D., Superintendent, Royal Infirmary. 1890
Thomson, David, I.A., F.R.I.B.A., 2 West Regent street. 1869

545 Thomson, George C., F.C.S., 23 Kersland terrace, Hillhead. 1883
Thomson, Gilbert, M.A., C.E., 97 Wellington st., *Vice-President.* 1885
Thomson, Graham Hardie, 2 Marlborough terrace, Kelvinside. 1869
Thompson, G. R., 204 George street. 1895
*Thomson, James, F.R.I.B.A., 88 Bath street. 1886
550*Thomson, James M., Glen Tower, Kelvinside. 1892
Townsend, C. W., Crawford street, Port-Dundas. 1890
*Tullis, David, St. Ann's Leather Works, Bridgeton. 1894
*Tullis, James Thomson, Anchorage, Burnside, Rutherglen. 1883
*Turnbull, John, jun., M.I.M.E., 18 Blythswood square. 1883
555 Turnbull, Robert, 122 Wellington street. 1895
Turner, George A., M.D., 1 Clifton place, Sauchiehall street. 1883
Turner, William, Rachen house, Helensburgh. 1875

Ure, William P., Regent Mills, Sandyford. 1893

Verel, Wm. A., Fairholm, Larkhall. 1883

560 Walker, Adam, 35 Elmbank crescent. 1880
*Walker, Archibald, M.A. (Oxon.), F.I.C., F.C.S., 8 Crown terrace, Dowanhill. 1885
*Wallace, Hugh, Bank of Scotland, 544 St. Vincent street. 1879
*Wallace, Wm., M.A., M.B., C.M., 25 Newton place. 1888
Wallace, William, M.A., Central Higher Grade School, Leeds. 1890
565 Warren, John A., C.E., 115 Wellington street. 1887
Watkinson, Wm. H., Whit. Sch., M.Inst.Mech.E., Professor of Steam and Steam Engines in the Glasgow and West of Scotland Technical College. 1893
Watson, Archibald, 5 Westbourne terrace. 1881
Watson, James, 25 Sandyford place. 1873
*Watson, John, 205 West George street. 1886
570 Watson, Joseph, 225 West George street. 1882
*Watson, J. Robertson, M.A., Professor of Chemistry, Anderson's College Medical School. 1891
*Watson, Thomas Lennox, I.A., F.R.I.B.A., 166 Bath street. 1876
*Watson, Sir William Renny, 16 Woodlands terrace. 1870
Welsh, Thomas M., 3 Prince's gardens, Dowanhill. 1883
575 Wenley, James A., Bank of Scotland, Edinburgh. 1870
Westlands, Robert, 4 Dixon street. 1869
Whyte, A. C., L.D.S., 42 Dundas street. 1892
*Whitson, Jas., M.D., F.F.P.S.G., 13 Somerset place. 1882
*Whitelaw, Thomas N., 87 Sydney street. 1892
580 Whytlaw, R. A., 1 Windsor quadrant, Kelvinside. 1885
Widmer, Justus, 21 Athole gardens. 1887
Wield, John, 9 Barns street, Ayr. 1895
Williamson, John, 65 West Regent street. 1881
Wilson, Alex., Hydepark Foundry, 54 Finnieston street. 1874
585 Wilson, David, Carbeth, by Killearn. 1850
Wilson, John, C. E., 154 West George street. 1895
Wilson, Robert, Glasgow Water Trust, City Chambers. 1893
Wilson, William, Virginia buildings. 1881
Wilson, William, Lord Carlisle's School, Bulmer, York. 1889
590 Wilson, W. H., 21 Hope street. 1881
Wingate, Arthur, 10 Prince's gardens, Dowanhill. 1882
*Wingate, John B., 7 Crown terrace, Dowanhill. 1881
Wingate, P., 14 Westbourne ter. 1872
Wingate, Walter E., 4 Bowmont terrace. 1880
595 Wood, James, M.A., Glasgow Academy. 1885
Wood, Wm. Copland, Turkey-red Works, Alexandria. 1883
Wood, W. E. H., 40 Candleriggs. 1891
*Wood, Wm. Jas., 38 Cochrane street. 1893
Wright, Robert Patrick, Glasgow and West of Scotland Technical College. 1895

600 Yellowlees, D., M.D., LL.D., Physician-Superintendent, Gartnavel. 1881
Young, John, 2 Montague terrace, Kelvinside. 1885
Young, John, 88 Renfield street. 1881
*Young, John, jun., M.A., B.Sc., 38 Bath street. 1887
*Young, Thos. Graham, Westfield, West Calder. 1880
605 Younger, George, 166 Ingram street. 1847

INDEX.